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Rock Art Management and Landscape Change: Mixed Field Assessment Techniques for Cultural Stone Decay

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Mixed Field Assessment Techniques for Cultural Stone Decay

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of the requirements for the degree of
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by

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ABSTRACT

As tourism continues to grow as one of the world's most ubiquitous markets, the development and promotion of non-invasive techniques for cultural stone decay analysis and landscape change are vital to establishing conditional base-lines to best aid cultural heritage management (CRM) efficacy. Using rock art as a medium, this dissertation presents three independent case studies employing the Rock Art Stability Index (RASI) and repeat photography to explore the merits of mixed rapid field assessment techniques in relation to CRM and heritage tourism. While rock art is only one example of irreplaceable world heritage resources, examining how they decay and what methods can effectively quantify their change provides valuable data leading to a better understanding of human/environment interaction within the context of tourism and cultural resource management. The first case study examines the applicability of combining the two methods on rock art in the Arkansan Ozark region, showing considerable promise. The second addresses the temporal flexibility of the mixed methods on rapidly changing, and highly impacted, rock art sites on Grenada, West Indies, demonstrating the method pairing's tremendous monitoring and emergency response potential. The third case study explores adapting RASI to analyze other forms of cultural stone by employing the mixed methods on selected hewn monuments in Petra, Jordan, aptly identifying a critical disparity between appearance and stability. Ultimately, each case study exemplifies different aspects of cultural stone decay and modern challenges: from initial preliminary evaluations to assessing the impact of uninformed conservation efforts, and examining the influences of mass tourism and human interaction at heritage sites. Mixed field techniques effectively highlighted both the need for and benefits of employing such methods for rock art management, cultural stone stability, and global heritage management.

Keywords: *Cultural Stone Decay, Heritage Tourism, Rapid Field Assessment, Repeat Photography, Rock Art, Rock Art Stability Index*

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DEDICATION

This dissertation is dedicated to Calvin: for being my faithful writing companion, sounding board, and helping me remain myself throughout this process. You will always have my love and thanks.

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LIST OF ABBREVIATIONS AND ACRONYMNS

AAS .... *Arkansas Archeological Survey*
ACOR .... *American Center of Oriental Research*
CARCIP .... *Conservation and Restoration Center in Petra*
ADoPT .... *Arkansas Department of Parks and Tourism*
CRM .... *Cultural Resource Management*
CSSI .... *Cultural Stone Stability Index*
GCI .... *Getty Conservation Institute*
GIS .... *Geographic Information Systems*
GPS .... *Global Positioning Systems*
ICOMOS .... *International Council on Monuments and Sites*
MAREP .... *Market Access and Rural Enterprise Development Program*
NGO .... *Non-Governmental Organization*
NHPA .... *National Historic Preservation Act*
NPS .... *National Park Service*
NSF .... *National Science Foundation*
OUF .... *Operation Urgent Fury*
PDTRA .... *Petra Development and Tourism Regional Authority*
PNT .... *Petra National Trust*
PTM .... *polynomial transform mapping*
RASI .... *Rock Art Stability Index*
RFA .... *Rapid Field Assessment*
RLICC .... *Raymond Lemaire International Center for Conservation*
RP .... *Repeat Photography*
SEM .... *Scanning Electron Microscopy*
SRER .... *Santa Rita Experimental Range*
TWL-CRMI .... *Temple of the Winged Lions Cultural Recourse Management Initiative*
UNESCO .... *United Nations Educational, Scientific, and Cultural Organization*
USFS .... *United States Forest Service*
WHC .... *World Heritage Council*
XRD .... *X-ray Powder Diffraction*

CHAPTER 1: INTRODUCTION

“Rock art as the manifestation of human conceptual thought and beliefs by traditional societies has endured for longer than any other global artistic tradition.”

- Sanz (2012, p. 491)

A genuine world heritage, rock art can be found across the globe representing countless societies and cultures, both living and long disappeared, but, despite their perceived resilience, rock imagery and cultural stone are far from immortal and are, in fact, in desperate need of new multidisciplinary theoretical frameworks and collaborative research tools to ensure their continued survival in an ever changing world. While Sanz (2012) eloquently described the considerable historic, ethnographic, and humanistic value of rock art, the sentiments of longevity can far too easily misrepresent the imagery’s inherent fragility—promoting the assumption that if it’s lasted this long, it’ll be around forever. Unfortunately, this is not the case. With advancements in technology, climate change, intensified travel and tourism, and a number of other global dynamics, rock art sites are now facing new and progressively more complex conservation and management challenges (McDonald & Veth, 2012; Whitley, 2001). Operating within this reality, in order to effectively conserve the world’s stone heritage, both for historic posterity as well as prolonging economic viability, the implementation of more holistic research methods becomes critical (Přikryl & Smith, 2007). When examining the influences of complex social phenomena, such as cultural tourism and/or heritage conservation, it is necessary to employ methods that capture all change without necessarily having to identify the cause—where the questions “what is anthropogenic?” and “what is natural?” are combined to simply ask “what is?”. In many cases the human and natural components are nearly indistinguishable anyway so instead of struggling to determine individual process driving change, the change itself becomes the focus of study—taking a step back to assess the big picture: what can be done to better evaluate and protect the multiple aspects of the world’s rock art resources and cultural landscapes?

In response to these questions, several prominent rock art scholars have issued calls for the development and implementation of more comprehensive rock art stability research to better inform cultural resource management policy (Whitley, 2006). For example, Clottes (2008b) describes rock art as "an endangered heritage worldwide", emphatically reiterating the need for better stability assessment techniques incorporating more elements of the landscapes and culture in which the resource exists—not just the stone but the context as well. He has argued many times that because rock art is so intimately tied to culture and people, that to truly conserve the resource the human components must also be included in research and mitigation (Clottes, 1997, 2006, 2008b). In an era of specialization and increasingly divergent scholastic disciplines, truly holistic and cross-disciplinary research can be difficult, but not impossible (Přikryl & Smith, 2007). A few interdisciplinary efforts have been made, such as Warke et al. (2003) who attempted to incorporate medical principles and terminology to categorize cultural stone decay, or Stray and Dahlin (1999), who combined climatology, environment sciences, and geomorphology to assess pollution impacts on rock art outside Oslo, Norway. However, there still remains a debilitating lack of collaboration among the sciences, academia, and practical disciplines in regard to rock art use and management. Therefore, to begin bridging the gap between traditionally divergent rock art stakeholders—scholars, conservators, tourism directors, local communities, etc.—this dissertation presents an alternative approach to heritage science and cultural resource management by demonstrating the merit and applicability of mixed field techniques in rock art stability research and cultural landscape management.

Addressing different challenges and pertinent research questions, three case studies were conducted using two validated rapid field techniques: the *Rock Art Stability Index* (RASI) and repeat photography (RP). The first case study illustrates the applicability and advantages of employing two complementary field methods in an assessment of three dramatically different rock art sites in the Arkansan Ozarks. A largely under-researched topic in Arkansas (Sabo III & Hilliard, 2005), this case study is among the first geologic assessments of the state's rock art resources, exemplifying the use of mixed field techniques in preliminary research and initial threat identification. The second case study demonstrates the temporal flexibility and potential for mixed methods to serve as monitoring or first response research tools following potential trauma or human impact. Analyzing data collected annually over a period of five years, this case study addresses the influences of tourism challenges, local interaction, and ill-informed conservation efforts on the famed Carib Stones of the Caribbean island of

Grenada. A little broader in scope, the third case study presents methodological adaptability by employing an alternative version of RASI—the Cultural Stone Stability Index (CSSI)—and repeat photography to analyze monument stability in Petra, Jordan. The massive classical city experiences hundreds of thousands of visitors annually with the sheer scale of the site discouraging traditional conditional assessments due to time and funding limitations (Paolini et al., 2012). The purpose of this case study is to show how the immense potential for adapted field techniques can provide Petra site managers with timely, and relatively comprehensive, evaluations of the stone facades essential to implementing appropriate conservation policies.

Within each case study, relevant literature, existing research, and necessary methodological details are provided, along with case-specific discussions and implications to the wider fields of cultural stone decay and landscape change. The case studies are then followed by a broader examination of the merits of mixed field techniques in heritage science, cultural resource management, and tourism. Before any research is presented, however, in-depth investigations of literary/theoretical and methodological contexts are provided. Rock art resources represent dynamic reservoirs of cultural, ethnographic, and economic value within a complex global setting. Determining effective multidisciplinary research methods to more holistically assess these various aspects of rock art sites is vital to their protection and continued survival as both cultural heritage *and* tourism resources.

CHAPTER 2: RELEVANT LITERATURE AND THEORY

Existing within a nexus of anthropology, history, geology, geomorphology, and countless other corresponding disciplines, managing cultural stone and rock art decay is a multifaceted endeavor (Figure 2.1). Within culturally significant sites, features can hold additional meaning and individual importance requiring scholars planning to assess the physical landscape to also acknowledge its cultural and historical context. Therefore, before any discussion of methodologies or case studies, an exploration of the theoretical and literary framework of the presented research is provided. A brief examination of place and value is offered before delving deeper into rock art landscapes, their significance, and existing conservation perspectives. This is followed by an overview of tourism and modern day challenges facing rock art and heritage management.

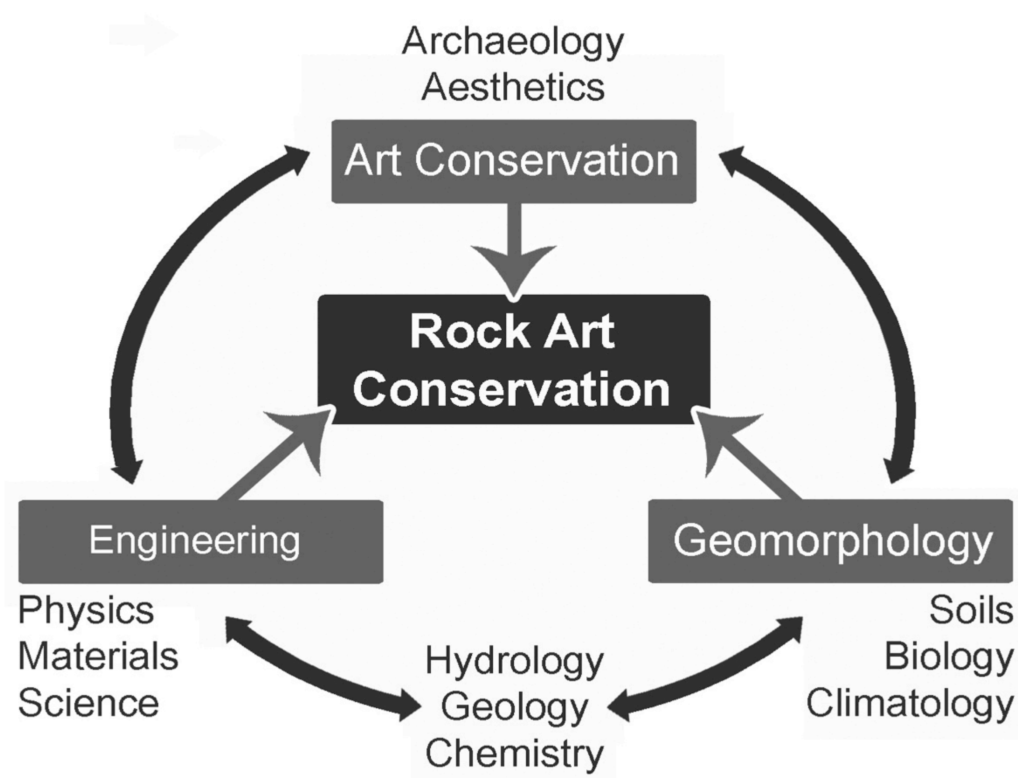


Figure 2.1: Graphic displaying the various interrelated fields of rock art and cultural stone conservation. Graphic from K. M. Groom (2017), modeled after Pope et al. (2002).

2.1 – SENSE OF PLACE AND VAULATION OF CULTURE

Filling a very specific niche within academic thought, landscape studies and humanistic geography have often had to defend their place as “real” scientific disciplines (Allen, 2013). However, these fields of study incorporate the less tangible, but equally important, elements of place and self to provide a theoretical and philosophical framework for all forms of geographic research (Inkpen & Wilson, 2013). Especially when investigating cultural landscapes or promoted ‘destinations’, it is vital to first explore what makes those places special, what gives them value. To accomplish this, the fundamental basics of landscapes and sense of place are defined, preceding an exploration of value, meaning, and aesthetics as they relate to geographic space. This is followed by a brief discussion of how these different elements produce cultural resources and concepts of cultural consumption and resource management.

2.1.1 – Landscape and Place

Defined and redefined throughout history, the concept of ‘landscape’ has held several meanings within geographic and academic literature (Howard, 2011). The term itself had been previously associated with seventeenth century Dutch *landschap* painters, imbuing connotations with the appearance or representation of place or scenery (Mikesell, 1968). Later adapted by the Germans in the late nineteenth century, *landschaft* (landscape) was used to describe a collection of forms in particular regions—often making distinctions between natural landscapes and cultural landscapes (Johnston et al., 2000). Bringing the discussion to America, Sauer (1925) defines landscape as “an area made up of a distinct association of forms, both physical and cultural” (p. 321)—highlighting what he terms “the interdependence of areal phenomena”. In this foundational publication, Sauer (1925) drew concepts from both the Dutch and German perspectives, but criticized considering cultural and physical features as separate entities when they both occupy and influence the same geographical space: the landscape.

Since then, a number of other significant works have been published contemplating the idea of landscape and where it should fit within academic and scientific research (Johnston et al., 2000). One of the most significant landscape publications from the late-twentieth century was Meinig (1979), an assortment of short essays describing different components of the same location—different perspectives of the same landscape—written by an impressive list of renowned cultural geographers, such as J.B.

Jackson, David Sopher and Yi-Fu Tuan. Although many of these were fairly anecdotal, this publication represents the diversity of landscape interpretation and opened the doors for future research on the complicated relationship between man and space (Allen, 2013; Howard, 2011; Johnston et al., 2000). Entire volumes have been written to discuss the various aspects of scenery, landscape, and place (Daniels et al., 2012; Howard, 2011). The connecting thread throughout most landscape literature is not a definition—as even textbooks self- admittedly "cannot promise that you will learn what 'landscape' is" (Howard, 2011, p. 1)—but a fundamental theme: incorporating the multiple ways in which humans interact with their surroundings, making culture inseparable from space.

Following similar logic, but from the perspective of self and perceptions, rather than external features, the philosophical concepts regarding sense of place essentially deal with how people see and perceive landscapes and their connection, or disconnection, with those spaces (Adamset al., 2001; Johnston et al., 2000). Equally as ambiguous as 'landscapes', sense of place has no set definition and refers more to a theoretical approach to human-environment interactions—how people see, appraise, and experience a physical or social space (Semken & Brandt, 2010; Tuan, 1977). Being so intimately tied to identity and human perceptions, the study and description of sense of place is incredibly diverse, addressing anything from vernacular landscapes and why people live where they do (Jackson, 1984) to how personal connections with the landscape aids natural conservation efficacy (Bray et al., 2003), even how place plays a role in online virtual realities (Relph, 2007). A number of scholars have attempted to create more sophisticated theoretical frameworks to describe sense of place, such as Massey (1997), who suggested a more progressive, rather than nostalgic or conservative, view on place, stating it should be considered "articulated moments in networks of social relations and understandings" (p. 66). Alternately, Allen (2011b) postures a more grounded approach applying actor network theory to landscapes and sense of place—presenting both viewer and place as active participants within a singular space. Several other frameworks have been proposed, but, similar to landscape, definitions and applications of sense of place remain fluid and enigmatic—though themes of value and experience remain fairly consistent.

There are several different identified ways in which places are imbued with perceivable value, including, but not limited to, history and aesthetics (Cresswell, 2015). Certain places hold meaning and value due to intrinsic associations with significant, often tragic, events in human history, such as Auschwitz, Poland (Agamben, 1999), or war memorials (Glassberg, 2001). Although, even sustained occupation in a singular region can bestow that place with a certain degree of value or interest, such as historic cities or regions (Johnston et al., 2000). To other scholars, aesthetics and beauty are key criteria in valuing a landscape. Goudie (2002) argues visual attractiveness in natural landscapes is not merely the product of geomorphologic processes, but actually critical to sustaining the discipline by creating intrigue and enticing new scientists to conduct research. Similarly, Dixon et al. (2013) discuss how aesthetics and the appearance of landscapes create a bridge between geomorphologists and artists, ultimately encouraging a cross-pollination of ideas and concepts towards a more holistic approach to landscape studies. Even rock art scholars have recognized the significance of visual quality and sense of place's impact the efficacy of cultural resource and heritage management and future conservation efforts (Heyd, 2003).

2.1.2 – Cultural Resources

Representing significant contributions to establishing sense of place and cataloging human existence throughout time, cultural resources come in many forms, including, but not limited to, archaeological remains, portable heritage (e.g. artwork, artifacts, handicrafts, etc.), intangible heritage such as language, way of life, and music, and significant and/or historic figures and people (King, 2012). However, for this dissertation, only one category in particular is relevant: non-portable tangible heritage (i.e. cultural landscapes, historic buildings, and cultural stone). In the instances when history, sense of place, and aesthetics are all culminated in a singular landscape, that location gains additional value as a 'cultural landscape' (Johnston et al., 2000; King, 2003)—a designation often accompanied by added tourism appeal and management challenges (du Cros & McKercher, 2015). The somewhat complicated relationship between culture and landscapes is described by Sauer (1925):

> *"The cultural landscape is fashioned from a natural landscape by a cultural group. Culture in the agent, the natural area the medium, the cultural landscape in the result." (p. 343).*

This active formation of cultural landscapes is typically organic and the result of sustained everyday human occupation and interaction with the physical environment, however, there are cases when cultural landscapes are purposefully manipulated or created to serve a specific purpose—most often for tourism or ‘cultural consumption’ (Johnston et al., 2000)(for more on this topic see *Cultural Tourism and Landscape Change* below).

Perceived as valuable to most people, the conservation and survival of particularly unique and/or significant cultural landscapes have lead to a number of policies, laws, and global agencies to safeguard them under the umbrella field of Cultural Resource Management (CRM)(King, 2012). Among the most famous is the United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage Program, where local management agencies of inscribed cultural and/or natural sites are held to stringent conditional requirements and criteria to maintain acceptable conservational standards—although accommodating increased tourism demand often contradicts several UNESCO criterions (Di Giovine, 2008). In the United States, several laws have been instated to protect historic properties—“a district, site, building, structure, or object included in or eligible for the National Register [of Historic Places]” -NHPA Sec 201(5)—such as the Antiquities Act (1906), the Historic Sites Act (1935), and the National Historic Preservation Act (1966) (NPS, 2006). Other nations around the world have similar policies, illustrating a universal desire to conserve the past for future generations.

However, global economies and cultures are not always so idealistic or easily managed, often necessitating more practical and adaptable approaches to CRM and heritage conservation. Several scholars from heritage and cultural tourism have identified a number of challenges and shortfalls within current CRM practices, such as unrealistic expectations for preservation efforts in actively touristed destinations (Smith, 2016) or conflicting attitudes and priorities between tourism developers and CRM agencies (du Cros & McKercher, 2015). In most cases, such publications call for more collaboration between conservation and tourism stakeholders as the best means to protect both the resource and economic viability (Timothy & Boyd, 2006). That said, some scholars advocate for an entirely new framework to establish simultaneous sustainable tourism and CRM from the ground up: Heritage Planning (Kalman, 2014). The main principles of heritage planning are based on lessons learned from past CRM/tourism successes and failures, including the intentional involvement of planners, conservators, *and* local stakeholder from the very inception of establishing a heritage/cultural tourism destination and adopting realistic standards and priorities throughout the development and management stages (Kalman, 2014). While this approach has considerable merit for resource conservation, its benefits are mainly limited to locales considering tourism development in the future, not where tourism and CRM activities are already prevalent or established. The dynamic relationship between cultural landscapes, heritage resources, and human interactions with both remain a prominent research foci in tourism, CRM, and geographic inquiry—with a critical need for research methods applicable to all three fields to promote more holistic investigations of the world's irreplaceable cultural landscapes (Přikryl & Smith, 2007).

2.2 – ROCK ART AS A CULTURAL RESOURCE

Encompassing a myriad of different landscapes, techniques, and eras, rock art remains a captivating and enigmatic record of human existence. Everything from carved bulls on the cliffs of southern Jordan, where no such animal could survive today (Harding, 1967; Henry, 2013), to life-size orca whales and reindeer sprawling glacially-polished mountains in Scandinavia (Hodgetts, 1999; Neiwert, 2015), humans have left their marks in stone. While there has always seemed to be a good deal of public fascination with rock art, any significant scientific and archaeological research of the phenomena has only emerged over the last few centuries (Whitley, 2001). What began as scholarly musing of "curious characters… cut into the rock" (Green, 1883) has developed into a genuine field of scientific and academic inquiry and investigation (McDonald & Veth, 2012; Whitley, 2001). Because the discipline of rock art research is still in its infancy, there are still several challenges and informational gaps in both theory and practice. Before more in depth discussion of such issues, a brief outline of rock art definitions and terminology is offered, followed by an overview of global rock art resources. After this, an overview of common rock art conservation and management policies, as well as the cultural perceptions behind them, is provided, preceded by a theoretical examination of rock's inherent cultural and scientific value.

2.2.1 – Defining Rock Art/Rock Imagery

To accommodate a myriad of styles, locations, and techniques, rock art has been loosely defined as "marks deliberately produced by humans on rock surfaces" (Sundstrom & Hays-Gilpin, 2011). Since the word 'art' often implies a certain degree of value/social connotations and/or indicated purpose, some scholars prefer the more objective term 'rock imagery' as a means to more holistically represent the resource (Dean et al., 2006; Loubser, 2001). Despite acknowledging the value of such vernacular distinctions, this dissertation will continue to use the term ‘rock art’, as it is more universally accepted and the most commonly searched reference term for the resource (Sundstrom & Hays-Gilpin, 2011). The use of the term is not intended to suggest any kind of unilateral function or cultural perceptions of the resource, but simply to maintain literary continuity with other research on the topic. Beyond terminology, rock art is traditionally divided into four major categories, organized by process and scale: pictographs, petroglyphs, geoglyphs, and intaglios (Whitley, 2005)(Figure 2.2).

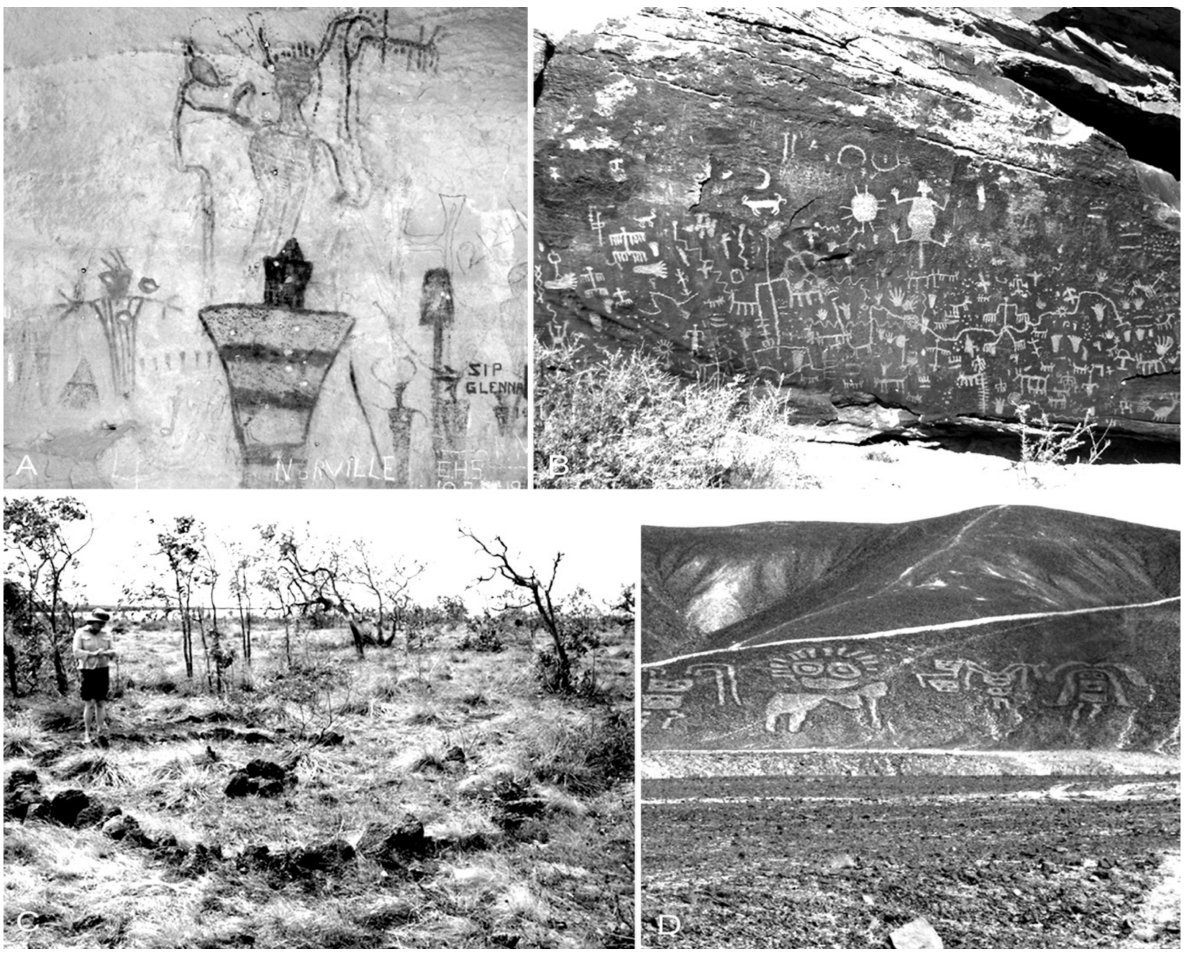


Figure 2.2: Examples of different rock art types. A) Fremont pictographs in Sego Canyon, Utah. Photograph by author, 2012. B) Hopi petroglyphs on Newspaper Rock in the Petrified Forest National Park, Arizona. Photograph by author, 2011. C) Aboriginal stone circles in Victoria, Australia. Photograph from Norris, Norric, Hamacher, and Abrahams (2012). “Nazca Lines” intaglios in Peru. Photograph by Casey Allen.

Both pictographs and geoglyphs are created using additive techniques: the application of additional material to the landscape and/or stone. More specifically, pictographs constitute imagery applied to a rock surface using a variety of substances, such as chalk, charcoal, paints, or any other form of pigmentation (Whitley, 2005). A number of the oldest and most famous rock art resources around the world are pictographs. Some of the more recognizable of these include the Paleolithic cave paintings in *Chauvet-Pont-d'Arc*, southern France, and the curious Fremont Native American motifs at Buckhorn Draw in San Rafael, central Utah. Operating on a more landscape scale, geoglyphs are created through the deliberate placement of stones or other earth material, ranging from small pebbles to large boulders, into distinctive patterns—most commonly geometric or circular motifs (Whitley, 2005). Among the most prominent geoglyphs are the Aboriginal *Wurdi Youang* stone circles in Victoria, Australia (Lane & Fullagar, 1980) and the Uffington White Horse in Oxfordshire, UK, where chalky while soil and stones are replentished by volunteers every year to maintain the large eqestrian design (National Trust, 2016).

Alternately, subtractive rock art techniques (i.e. petroglyphs and intaglios) involve the deliberate removal or displacement of topical material to produce patterns in the contrasting exterior and interior surfaces. Utilizing a variety of different methods, petroglyphs are essentially designs created on rock faces by juxtaposing the weathered or coated surface with the freshly exposed interior (Sundstrom & Hays-Gilpin, 2011). Techniques for removing rock coatings and surface material range from percussion methods, including pecking and engraving/carving with chisels or other tools, to controlled abrasion, such as incising and/or scratching (Whitley, 2005). Some petroglyphs are even created via polishing, where images are created by altering the appearance of the stone's surface without actually removing material—such as the numerous zoomorphic motifs found throughout Norway and Sweden (Bakka, 1975). Internationally recognized examples of petroglyph sites include Newspaper Rock in the Petrified Forest National Park, Arizona, *Khaz'ali* Canyon in the Wadi Rum Protected Area, Jordan, and *Twyfelfontein* in northwestern Namibia. Much larger, intaglios are grand figures formed by removing overlaying soils, vegetation, or desert pavements across a landscape, ultimately creating patterns in the uncovered subsurfaces. The famous *Nazca* Lines in coastal Peru may be among the most iconic intaglios in the world. Although they represent two distinctively different techniques (subtractive versus additive), many consider intaglios a subset of geoglyphs, which are sometimes defined without specific methods as simply “earth figures, usually monumental in scale” (Whitley, 2005 p. 828).

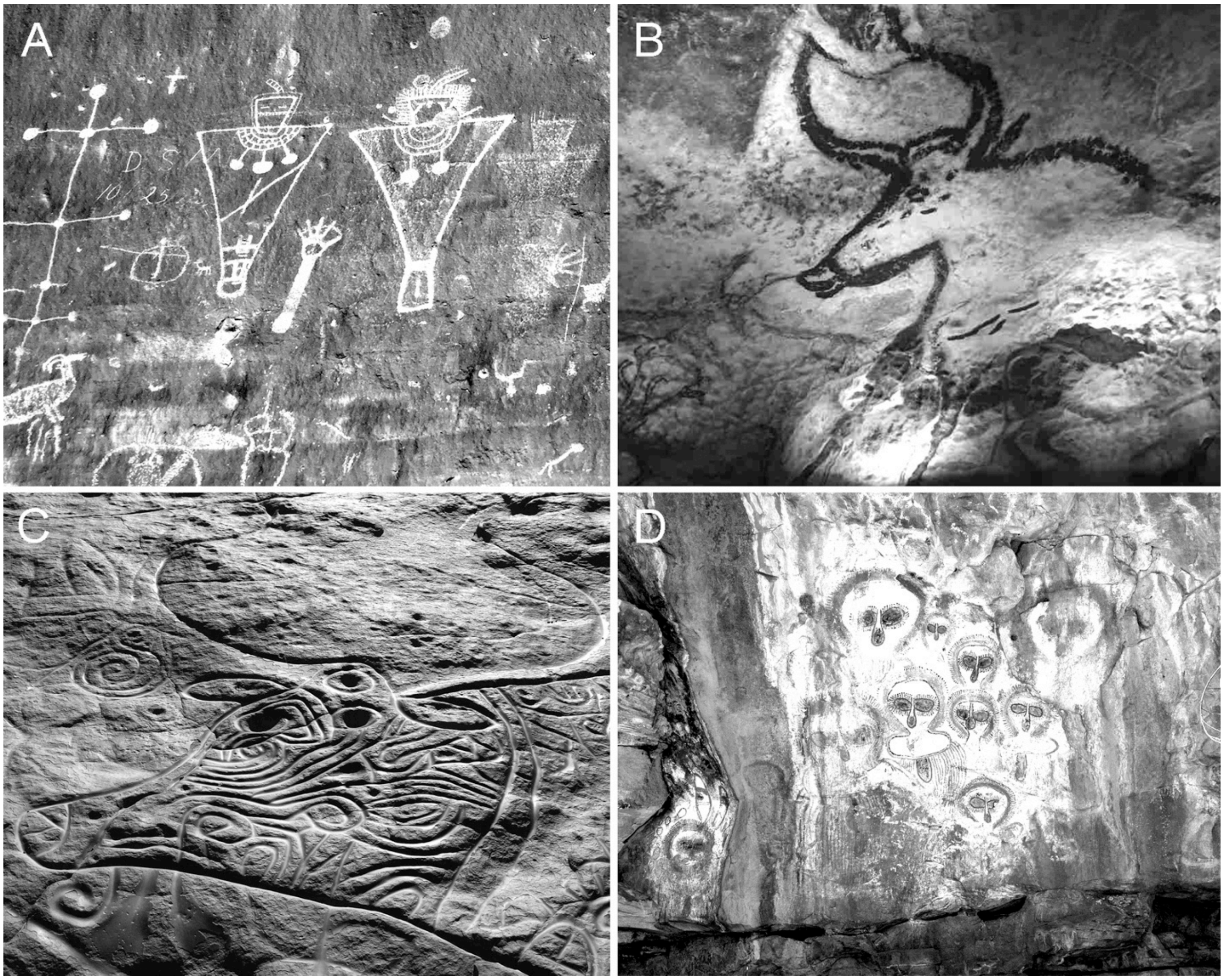


Figure 2.3 – Examples of rock art styles from around the world. A) Fremont Native American petroglyphs in Sego Canyon, Utah. Photo by author, 2012. B) Replicated bull from Lascaux cave, France. Photo from Beardsley (2017). C) Bubalus anticus engraving from Tin Taghirt, southern Algeria. Photo by Linus Wolf, 2011, WikiCommons. D) Aboriginal pictographs on the Barnett River, Mount Elizabeth Station, Australia. Photo by Graeme Churchard, 2013, WikiComons.

2.2.2 – Rock Art Around the World

A true world heritage resource, rock art can be found on nearly every continent spanning a variety of environments, lithologies, social contexts, and historical time periods (Clottes, 1997; Whitley, 2001). While styles and techniques inherently vary from person to person, there are certain patterns that arise among rock art created in different geographic regions (McDonald & Veth, 2012)(Figure 2.3). Granted, there are certain motifs and themes that are fairly universal—anthropomorphic figures and geometric designs, for example—but in many cases, rock art reflect their surrounding environments, cultures, and ecology (Henry, 2013; Whitley, 2001). With additive rock art, such as pictographs and geoglyphs, the relationship between rock art and location is even more intimate, as most paints, pigments, and other materials in their creation were likely locally sourced (Malainey, 2011; Russ et al., 2012)—creating meta-art of sorts: images *reflecting* the landscape made *of* the landscape. For this dissertation only four of the world's most actively researched rock art regions will be discussed: North America, Europe, Africa, and Australia.

North American Rock Art

Despite encompassing a significant expanse of landmass, much of North American rock art can be categorized into two general groups: Archaic (i.e. non-agricultural) and Agricultural (Whitley, 2001). The assumption in this separation is that the dramatically different lifestyles of hunter-gathers and farmers influenced the patterns, techniques, and motifs of each group's rock art (McDonald & Veth, 2012; Schaafsma, 1985; Sundstrom & Hays-Gilpin, 2011). For example, a good portion of Archaic rock art feature hunting scenes, prey animals such as deer, and landforms marking productive hunting grounds (Turpin, 2001). Alternatively, Agricultural rock art tends to be more concentrated—due to higher sedentary tendencies—and more often depict religious and ceremonial images with a greater degree of regional variation (Bostwick, 2001). Some areas of North America house images from both groups, such as the Great Basin in the US Southwest, either indicating coexistence or long-term habitation spanning the tenure of both societies (McDonald & Veth, 2012; Whitley, 2001).

Within both North American Archaic and Agricultural rock art groups, several regional patterns emerge, most famously identified in the landmark surveys of archaeologists Grant (1981) and Wellmann (1979). While there are a few subtle differences between the geographic regions presented by Grant and Wellmann, the broader similarities in observations, discussions of patterns, and basic regional divisions of style and media lead to the establishment of relatively well-accepted sub-regions of North American rock art. Each region is associated with specific rock art characteristics, such as technique, styles, and motifs, as well as suspected tribes or native peoples from the area. For example, the central desert of the Baja peninsula has been dubbed the 'Great Mural Region' for its unique monolithic anthropomorphic and zoomorphic pictographs painted with intricate detail and dual-tone colorations bisecting many of the figures (Crosby, 1975; Grant et al. 1974).

Of course, the boundaries between regions are approximate with a certain degree of overlap or permeation between regions and general universal patterns exist. The US Southwest and Great Basin regions, for instance, were—and still are—home to a wide variety of Native American Tribes, each with distinctive rock art styles and patterns. Some of the most prolific North American rock art sites, such as the Petrified Forest National Park (AZ), Petroglyph National Park (NM), and large portions of southern Utah, house rock art from a variety of overlapping Native American tribes including, but not limited to, Fremont, Hopi, Zuni, Anasazi, Hohokam, Mogollon, and Sinagua (Bostwick, 2001). While each tribe has unique styles, such as the curious triangular bodies and headdresses of the Fremont, and motifs, e.g. the soul-consuming *Nata'aska* of the Hopi, most share the same rock art type: pecked or incised petroglyphs (Turpin, 2001; Whitley, 2001). With its abundance of rock art, the US Southwest has attracted the most scientific attention but each of the sub-regions defined by Grant (1981) and Wellmann (1979) contain numerous and interesting resources, such as the Shamanistic pictographs of the Algonkain People in central Canada (Turpin, 2001) and the winged serpents found in the Eastern Woodlands and Mississippian regions (Sabo III, 2005a).

European Rock Art

Similar to North America, much of Europe's rock art can be divided into two major groups—although these are based on age instead of lifestyle: Paleolithic and post-Paleolithic (Whitley, 2001). Predominantly cave paintings and pictographs, roughly 350 Paleolithic rock art sites have been documented across Europe, with the large concentrations in France and Spain (Clottes, 2001), some of the most famous including the Chauvet and Lascaux caves in France and Altamira Cave in northern Spain (Clottes & Geneste, 2012; Conkey et al., 1980; Valladas et al., 2001). Reflecting the dramatically different climate of Earth's most recent major Ice Age, Europe's Paleolithic rock art feature abundant fauna, flora, and zoomorphs—some in remarkable detail and precision (Clottes & Geneste, 2012).

Several now-extinct Ice Age species are clearly identifiable in European rock art from this time, including mammoths, woolly rhinoceroses, and cave lions (Clottes, 2001). Even a number of mega-fauna are depicted in Europe, such as the pair of *megaloceros*—a large deer with immense antlers—in Cougnac, France (Clottes, 2001). Some of the more fantastical figures include human-animal chimeras, such as the *therianthrope*, a part-human part bison, playing musical instruments—representing the invention of tools and advancements in day-to-day technologies in the region (Clottes, 2008a). There have been several efforts to date Europe's Paleolithic rock art, both contextually (Breuil, 1952) and with modern scientific dating methods (Pettitt & Pike, 2007; Pike et al., 2012), with dates spanning nearly 25,000 years of human occupation in Paleolithic Europe (Clottes, 2001).

Covering a wider area, post-Paleolithic rock art in Europe is more spread out, mainly engraved petroglyphs, and stylized by region: Northern Europe, Atlantic Coast, and Alpine/Central Europe (Bradley et al., 2001). Much of the documented rock art found in Northern Europe are concentrated in the Nordic countries and northern Russia, with some of the most famous holding UNESCO world Heritage Status including the Alta petroglyphs in northern Norway (Hood, 1988). Located mostly near waterways and coastlines, aquatic zoomorphs and fishing/boating apparatus are common motifs found throughout the region (Neiwert, 2015). Unfortunately, significant language and cultural barriers have limited international collaboration between Nordic and Russian rock art scholars (Bradley et al., 2001). Further to the southwest, post-Paleolithic rock art along Europe's Atlantic coast, including the UK and Ireland, has historically experienced significantly less academic attention than their better-known Paleolithic counterparts, with concentrations of research being conducted in Iberia (Bradley, 1997) and northern Britain/Ireland (Nash & Chippindale, 2002). Despite interesting and significant motifs and styles, most work conducted on Atlantic rock art remains basic documentation and interpretation (Bradley et al., 2001). Further inland, approximately 25 post-Paleolithic rock art sites spatter the Alps Mountain Range, depending on site definitions or combination of adjacent sites (Bradley et al., 2001), mostly restricted in Northern Italy and France. Vastly outsizing any other sites in the region, two locales dominate Apline rock art research: Mont Bego, a single French peak barely over the Italian border covered with over 30,000 engraved figures (Chippindale, 2004; de Lumley et al., 2015) and the twin Italian valleys Valcamonica and

Valtellina in the south-central Alps with an estimated 300,000 individual figures (Fossati, 2015; Nash & Chippindale, 2002).

African Rock Art

With the Sahara Desert serving as a massive natural boarder, African rock art is commonly divided into the two same regions seen in countless World Regional textbooks and geographic studies: Saharan and Sub-Saharan. More aligned with Middle Eastern cultures and traditions, Saharan rock art shares several qualities with Arabian rock art (Červìcek, 1978)—such as abundant camel motifs and caravan scenes similar to those found in Oman and Saudi Arabia (Nayeem, 2000). Created largely by nomadic travelers, rock imagery (mainly domestic animals and wild Savannah zoomorphs) can be found across most everywhere throughout the Sahara, except various ergs where rocks are practically non-existent (Muzzolini, 2001). Consisting of both petroglyphs and pictographs—although the former is far more ubiquitous—Saharan rock art is far from homogeneous, or even easily divisible into definitive groups or sub-regions.

Despite inherent organizational challenges, some scholars have categorized Saharan rock art into three major ‘schools’ via standard ethnographic classifications (e.g. age, style, and motif): Naturalistic Bubaline, Tazina, and Libyan Warrior (Muzzolini, 2001). Found mainly in the Saharan Atlases and the Mathendous Basin (Libya), Naturalistic Bubaline consist mainly of engraved zoomorphs (including elephants, extinct giant buffalo, rhinoceros, hippopotamus, and assorted antelope), mythical scenes featuring various chimeras, as well as sexual images of masked men and “women with open legs” (Jelínek, 2000; Muzzolini, 2000). Located mainly in southern Morocco and around the Rio de Oro, Tazina petroglyphs almost exclusively depict schematic zoomorphs with exaggerated features in what early scholars describe as a “fantastical” style (Flamand, 1899; Gsell, 1901). Much more localized, Libyan Warrior glyphs are, as the name implies, engraved anthropomorphic battle scenes and armored warriors with spears practically confined to areas around to Air and Adrar des Iforas, Libya (Le Quellec, 2008; Liverani, 2000). Pictographs are also found in Saharan Africa, but in significantly fewer numbers and only in highly localized areas (Muzzolini, 2001).

Attracting significantly more academic and scientific attention than the chaotic Saharan imagery, literature pertaining to sub-Saharan rock art is abundant—especially in South Africa, where a number of world-famous rock art sites exist (Duval & Smith, 2013). Pictographs and cave paintings of the Southern Artistic Tradition—incorporating the works of San and Bushmen indigenous tribes south of Zambezi River—are touted as "the most important body of prehistoric art on the continent" (Garlake, 2001), p. 638). Part of a single long-lasting tradition, South African rock art, mainly anthropomorphs and zoomorphs, are typically very colorful, highly detailed, and display considerable artistic skill (Garlake, 1987; Willcox, 1963). Considered by some as the "earliest examples of representational art" (Lewis-Williams, 2013), San and Bushman rock paintings have a long history of anthropologic, ethnographic, and iconographic research spanning centuries (Fourie, 1928; Lewis-Williams, 1998; Werner, 1908). The issues of religion, entity, and relationships presented in San rock art are still being debated in modern academia (Garlake, 2001; Solomon, 1997). With so much attached meaning and value, a number of rock art sites in South Africa, such as uKhahlamba/Drakensberg, are inscribed in UNESCO's World Heritage Program (Duval & Smith, 2013). Unfortunately, many of these same sites are now struggling to maintain image conservation among growing tourism demands and over-stretched management resources (Hoerlé, 2005; Mol & Viles, 2010).

Australian Rock Art

Geographically isolated and culturally private, Australian indigenous rock art is remarkably unique and still largely enigmatic (Chaloupka, 1993; McDonald & Veth, 2012). Over 100,000 different rock art sites have been documented across the island continent—most of which are clustered in 30 major regions (Flood, 1997; Layton, 1992). Both ancient and modern Aboriginal people have a very active and organic relationship with their rock art, often revisiting single locations and adding figures/motifs each time—resulting in intricately overlain murals of overlapping figures, hands, and patterns (Taçon, 2001). These multi-layered panels have allowed some scholars to use basic stratigraphic techniques to create estimated chronologies for a handful of the bigger sites (Langley & Taçon, 2010; Lorblanchet, 1992), however, inefficient data prohibits the creation of any kind of reliable chronosequence necessary for more calibrated scientific dating (Taçon, 2001). Aboriginal rock art also encompasses a wide variety of types, including geoglyphs (Norris et al., 2012), pecked and engraved petroglyphs (Lorblanchet, 1992), as well as pictographs created with typical materials (i.e. charcoal, paints, plant pigments)(David et al., 2013) but also more unusual substances such as resin and beeswax (Chippindale et al., 2004).

Spanning tens of thousands of years, much of the rock art across Australia exhibit a number of stylistic and thematic shifts throughout time. Among the oldest rock markings are ancient cupules marking significant landforms (e.g. good hunting grounds or sources of water), particularly concentrated in northern territories (Taçon, 2001). Based on nearby contextual archaeological evidence, these first engravings could have been created as long as 120,000 years ago (Flood, 1997). The earliest designed figures, designated as “Panaramitee”—though the term is hotly debated (Bednarik, 2010; Layton, 1992)—were soon to follow and designate a surge of human exploration across the continent (Taçon, 2001). Mimicking natural patterns such as animal tracks, spirals, and concentric circles, some scholar suspect these are trackers’ markings labeling features of the landscape (Bednarik, 2013; Taçon, 2001)—some speculate this shift was a direct response to Australia’s megafauna extinction event (Flood, 1997; Roberts et al., 2001). During the Pleistocene, indigenous populations divided into tribes and became more territorial—a transition marked with stylistic divergence and localization of rock art appearances (Taçon, 2001). For instance, abstract linear grooves called ‘finger fluting’ that cover large portions of soft limestone outcrops in southern Australia (Flood, 1997) are dated to roughly the same period as early experimental pictographs and stencils in the greater Arnhem Land region (Chaloupka, 1993). Figurative motifs, first zoomorphs and then anthropomorphs, came next, although the exact dates for this progression are still uncertain (Taçon, 2001).

As indicated in this brief review, there are still countless unanswered questions regarding Australia’s curious and enchanting rock art with numerous opportunities for future research. Among the more promising and inspiring scientific advancements in Australian rock art research is the major shift in academic paradigms and prolific inclusion of local knowledge and collaboration with Aboriginal elders (Goldsmith, 2014; Taçon, 2001). Making the effort to begin reconciling a complicated history, the recognition and validation of Aboriginal insights by scientists, as well as elders sharing private, or even sacred, knowledge with outsiders represents the incredible value of rock art as a means to bring people together in the universal search for understanding. Only one group may have created the imagery, but together everyone can enjoy it, question its meaning, and explore its past to enlighten the future.

2.2.3 – Value of Rock Art

The immense value of rock art is frequently obscured or overlooked in modern science as it is often grouped together into larger categories—e.g. tangible heritage, archaeological remains, cultural resources (Smith, 2016; Timothy & Boyd, 2006). Paralleling the development of human societies, ideologies, language, and so many other cultural traits now taken for granted, rock art essentially represents the beginning and mankind's journey through time. Uniquely tied to the landscape, rock art illustrates the progression of human existence throughout history. The interpretation of rock art's purpose, meaning, and significance are major topics of investigation for scholars from a number of fields, including anthropology, history, geography, and ethnography, but ultimately the practice remains fairly speculative (McDonald & Veth, 2012; Whitley, 2001). Some panels are thought to portray simple daily activities, such as hunting or prayer, while others might tell the story of a voyage across the landscape via map glyphs (Groom & Poole, 2010; Groom & Thompson, 2011). Others may be remembrances, such as the Grenadian "Big Cat" petroglyphs, widely considered as the Arawak people's homage to the felines of South America (Hayward et al., 2009). Of course, in regions where indigenous populations still actively interact with ancestral rock art, such as Native Americans in the US Southwest and Australian Aborigines, the meanings of particularly religious or sacred rock images are more easily discernable—if only within certain circles or with tribal permission (Goldsmith, 2014; Groom & Thompson, 2011).

So, without the ability to validate or confirm hypotheses, why try to explain rock art at all? Many scholars have pondered the value of interpretative investigations with most concluding even theories, content, or the mere *presence* of rock art can reveal significant information about past societies (Alberti et al., 2013; Solomon, 1997). For example, Layton (2001) discusses how the emergence of horse and European-style ship motifs in Aboriginal paintings, independent of intended purpose or creator, document a pivotal era in Native Australian history. In locations such as Wadi Rum, Jordan, petroglyphs and inscriptions—regardless of motif or content—represent more than 12,000 years of continual human occupancy (WRPA, 2016). In fact, the value of Wadi Rum's rock art legacy was recognized by the park's induction into the UNESCO World Heritage Program:

> *"The petroglyphs trace the evolution of human thought, the long term patterns of pastoral, agricultural and urban human activity in the Arabian Peninsula, and the environmental history of a distinct region…" (WHC, 2011)*

In many ways, even the quest for understanding and the questions themselves hold a certain degree of cultural importance as they force scholars to engage with the past and wonder about the lives of other people from another time (Brady & Taçon, 2016). These questions can be academic in nature, or personal—what can these images reveal about the lives of their creators? Because interpretation is so often individualistic, anyone has the ability to entertain questions regarding rock art and its value (Alberti et al., 2013; Sundstrom & Hays-Gilpin, 2011). Needless to say, beyond content or interpretation, rock art holds considerable historic and cultural value—both for ancient societies and today.

Additionally, with the spread of tourism and advancements in technology and regional accessibility, rock art has begun accruing economic value as well. Offering intimate interactions with the landscapes and memories of long-gone civilizations, rock art sites around the world have been promoting themselves as premiere travel destinations and must now protect the imagery not only for posterity, but to maintain their economic viability as tourism recourses (Deacon, 2006; Duval & Smith, 2013). Representing a new source of income, some developing nations have put forth extra effort to discover, record, and promote new rock art sites for tourism—e.g. the Black Desert petroglyphs recently announced in Eastern Jordan (Plummer, 2016). Such discoveries advance scientific knowledge of the occupational history of the region while also providing additional revenue and motivation for further exploration and research—as long as the precarious balance between conservation and consumption can be maintained (Deacon, 2006).

2.2.4 – Rock Art Management and Perceptions

That said, certain characteristics of rock art hold different value depending on governing cultures, perceptions, and priorities—variances reflected in the diverse approaches to rock art management and upkeep. In general, global attitudes regarding rock art conservation fall along a spectrum between protecting rock art's content (i.e. motifs and designs) or context (i.e. the physical panel). In many cases one has been safeguarded at the detriment of the other. Of course, as with any spectrum, there are some entities operating somewhere in the middle, but even these usually prioritize one trait over the other—ultimately influencing management policy and prescribed action.

For most content-centered management plans, documentation and clarity are considered paramount. A number of technological advancements, such as 3D scanning, digital photography, and advanced photogrammetry, have allowed researchers to document and record rock art motifs in remarkable detail (Barnett et al., 2005; Trinks, 2005). In some opinions, precise digital 3D documentation is all that is necessary to "permanently preserve prehistoric rock art" (El-Hakim et al., 2004, p. 990)—essentially making the physical resource obsolete after recording. The danger in this approach is the assumption that the technology of today is the best it will be and no other information can be obtained from the original resource. To an early rock art scholar examining a pictograph, being able to determine its age from a miniscule speck of carbon-rich pigment would seem impossible. What other kinds of future discoveries are modern scholars preventing by neglecting the physical form post-documentation? Even less technological documentation methods, such as rubbings, casts, and tracings can loosen small particles or damage the rock art in the long run (Sundstrom & Hays-Gilpin, 2011), but again, once the record is made, the status of the stone is suddenly inconsequential because the art has been documented.

Moving slightly down the spectrum, other management agencies focus on preserving the visibility and clarity of their rock art in situ, most commonly through restoration or enhancement. This approach, most common in Europe, involves continually updating the rock art so motifs and patterns are always clearly visible. Examples of such activities include the annual replenishment of the Uffington White Horse geoglyph in the UK (National Trust, 2016) or painting the carvings nearest trails in the Hjemmeluft World Heritage Site in Alta, Norway (Tansem & Johansen, 2008). In both cases, the intention is to make the motifs and content easier to see, despite negating any future archaeological research by contaminating the historic integrity of the resources (Whitley, 2001). This isn't a concern, however, because from their perspective these activities help prolong people's ability to see, share, and enjoy the images well into the future—thus protecting them (National Trust, 2016).

The alternative of this attitude rests in conserving the integrity of the scientific and historic condition of the rock art—even if this means limiting, or even prohibiting, access to the resource itself. This approach is more frequently adopted in the United States or nationally governed rock art sites (Whitley, 2001). The most common method from this school of thought is to keep the locations of rock art sites confidential or limit visitor access to a small selection of designated areas (Loubser, 2001)—such as viewpoints within US National Parks (Groom & Thompson, 2011; Whitley, 2006). Although, some agencies have employed more extreme measures, such as intentional internment or semi-permanently covering rock art for prolonged periods. A prime example is the Glasgow Cochno Stone in Clydebank, Scotland, which was buried in the 1960s to prevent unnecessary deterioration or exposure to environmental forces (Morris, 1989). The stone was actually fully excavated and digitally documented in late 2016 by scholars from Glasgow University and the Factum Foundation for Digital Technology in Conservation but was reburied once the survey was complete (BBC, 2016). The researchers plan to use 3d models and computer imagery to learn more about the stone, who made it, and how modern societies impacted the petroglyphs after it was exposed in the 1930 until it’s eventual internment decades later (BBC, 2016). The most obvious argument against this approach is inaccessibility of the rock art—why save it if no one can even see it?

However, as with most things, the vast majority of rock art management policies concentrate on finding some kind of balance—balance between conserving the rock art while also making it accessible to the public, at least in some way. Several rock art conservators insist the best policy for rock art management is to simply leave it alone and encourage others to do the same (Loubser, 2001; Sundstrom & Hays-Gilpin, 2011; Whitley, 2006)—but this outcome is rarely achievable. In reality, most rock art sites, especially those in public or well-known areas, must rely on visitor-generated income to fund damage mitigation and/or conduct research, creating a poorly-addressed cyclical relationship between tourism and conservation (Deacon, 2006). As a steadily growing force in the global economy, increased tourism puts mounting pressure on cultural resource management and tangible heritage around the world (du Cros & McKercher, 2015; Smith, 2016). For rock art, tourism could serve as an alternate source of revenue, but, if poorly managed, inherently fragile sites could be lost in the process (Dean et al., 2006). With so many rock art sites precariously teetering between starved conservation and unsustainable exploitation, the implementation of rapid field assessment techniques for rock art and cultural stone stability research is critical to establishing better policy and ensuring long-term resource survival (Přikryl & Smith, 2007).

2.3 – TOURISM AND CONTEMPORARY MANAGEMENT CHALLENGES

Described by S. Williams and Lew (2015) as “the desire of people to move in search of embodied experiences of other places”, modern tourism is a vastly complex global phenomenon. Within the last three decades tourism has become one of the largest and fastest growing economic sectors in the world (Jamal & Kim, 2005)—drawing the attention of the academic and scientific communities (Mitchell & Murphy, 1991). Tourism’s growth has been so rapid some scholars debate whether or not the academic community has been able to “keep up” (Franklin, 2003; Jamal & Kim, 2005). While the specific case studies and parameters differ, several common themes exist within tourism literature. These include but are not limited to the commercialization or commodification of space/culture for the consumption of the tourist (e.g. Bao & Su, 2004; Swanson & Timothy, 2012), economic consumption theories such as supply and demand of touristic resources (e.g. Formica & Uysal, 2006; Williams & Hall, 2000), the creation of “touristic cultures” (e.g. Crang, 2004; Dicks, 2004), and gaining a better understanding of how complex social processes are manifested in spatial configurations in the landscape (Hunziker et al., 2008). The ways in which tourism is conceptualized is also varied, with structures such as actor-network theory (Jóhannesson, 2005; Van der Duim, 2007), complex adaptive systems (Farrell & Twining-Ward, 2004), and interdisciplinary integrated frameworks (Jamal & Kim, 2005). It could even be argued that archeological frameworks, such as Human Ecodynamics (Kirch, 2007), could be applied to examine tourism landscapes.

While tourism is not the primary focus of this dissertation, it is a prominent challenge facing heritage and cultural resource management agencies—especially in developing nations where tourism is often a primary source of income (Archer et al., 2005)—and so worth discussing. Many management agencies struggle to maintain the precarious balance between protecting cultural resources and sustaining local livelihoods dependent on those resources. Beyond the economic and cultural issues, tourism can be quite taxing on the physical landscape as well (Ap & Crompton, 1998; Archer et al., 2005; Ringer, 1998)—an added complication for heritage management and of particular interest to this dissertation. To avoid unnecessary summarization of tourism's copious and diverse literature, this review will focus primarily on the relationships between tourism, physical landscapes, and cultural stone decay—beginning with broad global tourism, followed by the specialized area of cultural and archaeological tourism, ending with rock art tourism and current conservation and management challenges.

2.3.1 – Global Tourism and Geomorphology

In spite of dramatic increases in worldwide tourism activity over the past several decades, the definitions of the widely used terms 'Global Tourism' and 'Mass Tourism' are still under debate (Theobald, 2005a). While both terms may seem relatively self-explanatory—'Global Tourism' is tourism at a global scale—the reality is slightly more complicated as 'tourism' itself has no standard definition. The act of traveling has been an integrated part of human existence since the dawn of nomadic hunter and gatherers following prey herds and migrating with the seasons. Since then, humans have travelled for numerous reasons: religious pilgrimage, war, migration, trade, pleasure, and even the pure curiosity of what's out there. Were all these travelers actually tourists? What's the difference? The answer is complicated and little consensus exists within the tourism research community (Jamal & Kim, 2005). Etymologically, the term 'tour' comes from the Greek '*tornos'* and Latin *'tornare'* meaning 'a lathe or circle; the movement around a central point of axis' (Theobald, 2005a). The suffixes *–ism* and *–ist* add the action and participant components (i.e. tour*ism* and tour*ist*), leading some scholars to argue that tourism, like a circle, is a journey where the starting and ending points are the same—leaving home to go somewhere else before returning home (Theobald, 2005a). However, such a definition is over-simplified and useless when attempting to establish criterions of measurement or universal research parameters.

Several international committees, including the U.S. National Tourism Resources Review Commission (Theobald, 2005a) and the United Nations' Conference on Trade and Development (Taylor & Smith, 2007), have deliberated on the issue of defining tourism for industry standards. Both conceptual (Burkart & Medlik, 1981) and technical (Leiper, 1979) definitions have been presented, but the most commonly adopted definition is based on three elements: (1) purpose of travel, (2) distance traveled, and (3) duration of trip (Theobald, 2005a). It could be argued, then, that the addition of descriptors such as 'Global' or 'Mass' simply denotes the scope at which these parameters are considered and the number of participants—although this is still debated, as some scholars believe the significance and impact of tourism on such a large extent merits separate definitions (Frechtling, 2012). Regardless of the lack of universal definitions, scientific and academic research continues to explore the impacts and characteristics of mass global tourism.

Brandishing a number of academic buzzwords including ‘globalization’, ‘sustainability’, and ‘commodification’, much of the literature discussing tourism on a global scale is either theoretical or economical (Theobald, 2005b). Discussion topics range from humanistic explorations of self and relationships during touristic experiences (Pearce, 2005) and the role of nostalgia as a driver of tourism (Dann, 2005) to examining global tourism within scientific and economic frameworks such as carrying capacities (Brandt, 2011), thresholds (Caletrío, 2011) and maintaining economic viability (Tisdell, 2001). Some scholars even debate whether or not travel and tourism should even be considered an industry at all. Davidson (2005) strongly argues that tourism is actually an economic ‘sector’ requiring the collaboration of multiple industries—transportation, hospitality, food and drink, entertainment, so forth—and that promoting tourism as an industry diminished the complexity of what tourism truly is: a powerful social and economic phenomenon that can initiate significant financial and societal change. In agreement with Davidson, this dissertation refers to tourism as a sector instead of the more common, but less accurate, designation ‘industry’.

Despite the undeniable global influence of tourism, its physical impact and geomorphologic relationships, in both built and natural landscapes, remains disproportionately under-researched (Theobald, 2005b). Archer et al. (2005) insightfully introduce tourism’s complex relationship with the environment, stating: “Tourism, by its very nature, is attracted to unique and fragile environments…” (pg. 79). In essence, the distinctive and interesting aspects of nature that often drives the tourism industry are also among the most threatened by tourist activity. This is reflected in perceptions as well. In a Hungarian case study, Puczkó and Rátz (2000) found that most visitors declared “nature” as being the primary reason for their visit but also listed pollution and environmental damage as the most troubling effects of tourism. Caletrío (2011) outlines the problem of relying on “ecological thresholds”—points at which environmental degradation outweighs tourism appeal—to curb destructive tourism patterns by presenting ever-increasing tourism in a Mediterranean tourist destinations that have reached, and possibly, surpassed suggested theoretical thresholds. This duality of natural appeal and, sometimes in spite of, environmental deterioration leads to two distinctive approaches to tourism geomorphology research: change as a *result* of tourism and change as a *source* of tourism.

Being so closely tied to economic development, research on the resultant physical impacts of tourism often examines change in terms of costs and benefits (Lindberg & Johnson, 1997). With tourism's ability to boost struggling economies, certain scholars, as well as some host communities, consider the building or enhancement of tourism infrastructures as positive and necessary landscape changes, despite the environmental impacts of such development (Archer et al., 2005; Puczkó & Rátz, 2000). This becomes particularly controversial when discussing rapid over-development or poorly planned/executed construction threating the integrity of the tourism source—as seen in many parts of the developing world (Timothy & Boyd, 2006). Other major landscape alterations, such as dredging mangrove swamps for marinas and leveling forests for ski resorts, are among some of the more obvious research topics, along with more subtle but equally destructive issues such as waste management problems, pollution, damage from off-road vehicles, or the inadvertent introduction of invasive species into fragile environments (Archer et al., 2005). Some scholars have attempted to address these management concerns by identifying specific carrying capacities and thresholds to determine the "breaking point" of tourism landscapes (Brandt, 2011), although the strict definitions and applicability of carrying capacities are debated (Caletrío, 2011; Lobo et al., 2013). Others promote re-conceptualizing tourism impact by merging ecosystems, global change science, and complexity theory (Farrell & Twining-Ward, 2004). The apparent need to conceptualize and re-conceptualize tourism impact on landscapes may stem from the quasi-cyclical relationship between geomorphology and tourism. Mihai et al. (2009) discussed the relationship between tourism and "geo-heritage"—unique and valued geomorphologic features—as being reciprocal: The changing landscape serving as both the focus and result of tourism activity. Within this framework, determining geomorphologic cause and effect becomes much more difficult.

In reality, unique natural landscapes have served as tourism destinations since the conception of leisure travel, and as such geomorphology has played a major role from the beginning. Since the Ancient Egyptians first cruised the Nile, landscapes and the processes that create them have been tourist resources and natural heritage throughout history. The global significance, or at least perceived value, of particularly remarkable landscapes is communicated through inclusion in exclusive programs, such as CNN's "Seven Natural Wonders" and UNESCO's "Natural World Heritage List" (Badman, 2009). Within the United States, the National Park Service, affectionately called "America's best idea" (Runte, 1997), was established for the pure goal of protecting, and yet making accessible, the country's greatest natural landscapes. The founders of these programs might not have had tourism in mind during the design phase, but tourism and natural resources are now almost seemingly inseparable (Newsome et al., 2012). Entire branches of tourism, such as "ecotourism", are dedicated to experiencing, and sometimes attempting to recover (Rittichainuwat, 2006), the natural environment. While ecotourism is popularly represented as a "greener" form of tourism, many scholars warn of how oversimplifying the relationship between visitors and the environment could be misleading and leave the resource vulnerable (Beaumont, 2001). Considerable amounts of contemporary literature focuses on finding the balance between degradation and experience, impact and benefit, and the need for further research on the complex relationship between tourism and natural, as well as built, landscapes is emphasized within the tourism academic community (Archer et al., 2005; Butler & Boyd, 2000; Holden, 2007).

Since its conception, tourism has had an intimate relationship with geomorphology and landscape change, as well as conservation and management concerns. Throughout history, as people traveled to experience the world's natural and built landscapes, they leave a lasting impression on those places. From ancient Egyptian scribes documenting their journey on the walls of grand tombs to the Civil Conservation Corps building new trails and accommodations during post-Great Depression in the United States, tourism and geomorphology have been tied. With the abundance of tourism literature, it can be difficult to imagine that there is an informational lacuna as large as truly understanding this relationship. New, more holistic research methods, such as repeat photography, have the potential to fill this void and promote better long-term management policies. Vital to both the built and natural environments, sustainable development is a common theme within tourism literature. Numerous books have been written on the matter, such as <u>Sustainable Tourism Management</u> (Swarbrooke, 1999), <u>The Competitive Destination: a Sustainable Tourism Perspective</u> (Ritchie & Crouch, 2003), and <u>Sustainable Tourism: a Geographic Perspective</u> (Hall & Lew, 1998), but without a more comprehensive approach to researching the environmental impacts of tourism, progress is limited. Therefore, research on all aspects of geomorphology and tourism is necessary for effective conservation and resource survival.

2.3.2 – Cultural Tourism and Landscape Change

Among the oldest forms of special interest tourism, heritage-based or cultural tourism can be found worldwide and throughout history (Smith, 2016; Timothy & Boyd, 2006), although, much like tourism as a whole, defining what sets cultural tourism apart from other forms of travel is still widely debated (du Cros & McKercher, 2015). If considered in the broadest sense—the act of leaving one's own cultural to experience another—then all tourism, in one way or another, would be cultural tourism. Some scholars have attempted to narrow the definition with additional factors such as motivation: "The movement of persons … to satisfy their cultural needs and … to specific cultural attractions …" (Whyte et al., 2012, p. 10). Other definitions involve the pursuit of "meaningful experience [within a] unique social fabric" (Blackwell, 1997; du Cros & McKercher, 2015) or greater understanding of another way of life (Bachleitner & Zins, 1999; Hannabuss, 1999). However, motivation and experience vary person-to-person, making them inappropriate and ambiguous definitional controls. Alternately, McKercher and du Cros (2006) approach the issue from the supply perspective instead of demand:

> *"[Cultural tourism is] a form of tourism that relies on a destination's cultural heritage assets and transforms them into products that can be consumed by tourists. (pp. 211-212).*

When defined by resource instead of motivation, the intimate relationship between cultural/heritage tourism and geomorphology/physical landscape becomes much clearer. The decay and conservation of heritage resources such as historic buildings, archaeological ruins, temples, and rock art are no longer historical or aesthetical concerns, but practical—maintaining their viability for long-term economic potential. With considerable literature focused on the humanistic, economic, and social aspects of cultural tourism, issues of physical impact and landscape change—despite being paramount to cultural resource survival—are surprisingly under-represented in tourism research (Smith, 2016).

The majority of research that does exist on cultural tourism and landscape change, especially in built environments (e.g. buildings, cities, historic sites), incorporate some element of decay and adaptation. Processes driving the continual wear and tear of tourism in historic buildings, ruins, and other such man-made destinations are a primary concern for heritage tourism and CRM agencies (Timothy & Boyd, 2006). Researched processes have ranged from increased respiration humidity in a small sanctuary in Jordan exasperating decay (Paradise, 2010) to tourist desecration and vandalism of rock art panels in the American Southwest (Groom & Thompson, 2011). In addition to the deterioration of heritage, and, thus, tourism resources, the conversion of existing features to supply tourism needs (Di Giovine, 2008) along with looting, "souvenir hunting", and antiquity black markets (Dutton & Busby, 2002) remain prominent, yet under-researched, themes within cultural tourism research. The creation and adaptation of specialized academic fields, such as cultural geomorphology, have helped bridge the informational gaps between humans, the built environment, and processes of decay (Smith et al., 2008)—but more is needed to fully understand this dynamic relationship.

Adding another element of complexity, not all geomorphologic changes within built environments are the result of tourism development, and can, in fact, be the origin of tourism development. Some of the most obvious examples of this are ghost towns and ancient ruins. Would these places be as interesting or as popular if they were not in some form of decay? DeSilvey (2006) explored the idea of interpreting heritage decay as not a purely destructive force to be stopped but as a natural progression of time and memory equally important to that heritage. While her discussion is mainly anecdotal, the concept of decay *as* heritage is not uncommon within archeology (e.g. Edensor, 2005) and could be tied to tourism studies, especially heritage or cultural tourism. The crumbling shell of an abandoned pioneer town exemplifies the romance and interest of a bygone era (DeLyser, 1999)—something unobtainable with a replica or reconstructed destination. With the ever-increasing demand for "authenticity" in tourism experiences (Timothy & Boyd, 2006), it could be argued that decay and geomorphology will become key suppliers to meet that demand (DeLyser, 1999), although very little research has been done on this particular component of tourism studies.

Beyond the physical impacts of tourism, another major, and complex, component of tourism/heritage resource management is the *perception* of tourism impacts—by both the tourists and host communities. In a study on the viewpoints of tourism influence on one of Hungary's most popular vacation destinations, Lake Balaton, Puczkó and Rátz (2000) found that both tourists and locals showed concern for the environmental repercussions of tourism, though only the locals could provide concrete examples—suggesting a certain level of stereotyping on the part of the tourists. Timothy and Boyd (2006) discuss the common social psyche of developing worlds being concerned about heritage survival but giving little consideration to conservation efforts or making any substantial changes in consumption. This passive approach to heritage conservation, for both built and natural landscapes, may be due to the economic drive of tourism development. As might be expected, communities more financially dependent on tourism are more supportive of further tourism development, even when locals recognize negative impacts of tourism (Puczkó & Rátz, 2000). Perceptions are also heterogeneous among different stakeholders in the landscape, further complicating management strategies (Hunziker et al., 2008). Therefore, to address the physical ramifications of tourism within a realistic context of maintaining the basic desire of heritage survival, while also promoting economic viability, conservation, *not* preservation, becomes key to successful heritage/tourism management.

As one of the world's largest and fastest growing economic entities, tourism has become an influential global force with the potential to incite significant landscape change, either beneficial or detrimental, in both built and natural environments. With increasing accessibility to exotic and fragile environments, management agencies of these locales must meet mounting pressure to both conserve the cultural and/or natural integrity of their resources while also promote the sustainable tourism and economic growth necessary to do so. This is particularly true when addressing heritage tourism, where new challenges of increased tourism correspond with pre-existing heritage management difficulties facing agencies such as UNESCO and U.S. National Park Service. These agencies currently rely heavily on scientific and site stability monitoring methods that can be expensive, time-intensive, and/or potentially damaging to the sites they are appointed to protect. Therefore, the development and promotion of rapid non-invasive field assessment techniques are vital to establishing conditional base-lines to best aid heritage management efficacy.

2.3.3 – Rock Art Tourism

Despite being an emerging subset within cultural and heritage tourism, rock art tourism has received limited academic and scientific attention. Similar to archaeological literature, rock art resources are more often than not simply lumped into the wider category of "tangible heritage" and disregarded as separate resources within tourism studies (Smith, 2016; Timothy & Boyd, 2006). In the rare instances when rock art is specifically mentioned in tourism studies, they merely serve as examples of different conservation or educational policies (du Cros & McKercher, 2015). However, recognized by numerous global NGOs, such as UNESCO and ICOMOS, as significant world heritage resources, rock art sites around the world represent a unique blending of cultural and physical landscapes deserving specialized scientific attention (Sanz, 2012). In fact, over 35 of UNESCO's esteemed World Heritage Sites—including several 'mixed' sites—showcase rock art as key features (Sanz, 2012). This recognition not only reiterates the global value of rock art but also its potential to serve as prosperous and desirable tourism resources (Whitley, 2001).

Several rock art sites around the world, regardless of their UNESCO status, openly endorse rock art tourism by providing intimate interactions with ancient images and unique viewing experiences. A newer addition to the UNESCO World Heritage program, the vast iconic landscape of Wadi Rum, Jordan, boasts thousands of intricate petroglyphs and inscriptions—with their ages spanning from the Neolithic to Thamudic to the days of Independence and Lawrence of Arabia (Bille, 2012; Corbett, 2012; Farès, 2006)—all of which are prominently displayed on promotional materials and websites (Howard, 2015; WRPA, 2016). In peak tourist season, Khazali Canyon, one of Wadi Rum's most famous rock art sites, witnesses hundreds of visitors a day with little to no supervision (al-Zalabahi, 2016)(Figure 2.4A). Although many of the world's rock art sites remain relatively 'wild', other management entities have taken more controlled approaches to presenting rock art to tourists. For example, US National Park Service manages several properties with prolific Native American petroglyphs and pictographs, most of which are located in the US Southwest. One such park, the Petrified Forest National Park in Arizona, have several fenced trails and viewing areas near particularly interesting or significant rock art panels (see Figure 2.4B), but the majority of sites remain off limits to visitors without a park escort. Park supervisors then alternate which sites are used for "off trail' tours, largely based on conditional reports and research (Groom & Poole, 2010; Groom & Thompson, 2011). Alternately, after struggling for decades to mitigate tourism impacts (Delluc & Delluc, 1984; Graff, 2006), France's famous Lascaux Neolithic cave paintings can now be viewed via exact replicas in a nearby museum constructed from 3D scans of the original cave (see Figure 2.4C)(Deacon, 2006; du Cros & McKercher, 2015). That said, tourism also exists for

Figure 2.4: Examples of rock art tourism and impact around the world. A) Tourists in Wadi Rum's Khazali Canyon. The Narrow walkway forces visitors to stand extremely close to the rock art and use the cliff walls to stable themselves when necessary—adding potential stress on the canyon's petroglyphs. Photograph by Kathy Groom (with permission). B) Summer solstice marker panel at Puerco Pueblo, one of the public rock art sites at the Petrified Forest National Park. The Park has several such glyphs that line up with the noon shadow on the summer and winter solstices. Photograph from NPS (2015). C) Interior of the Lascaux Cave Museum with detailed replicas of the original cave paintings. Photograph by Beardsley (2017). D) Defacement of Freemont Native American pictographs in Sego Canyon, Utah. "Souvenir hunting" is not limited to small archaeological items; inconsiderate tourists have also purposefully removed sections of rock art—leaving scarred surfaces such as the one on this panel. Photograph by author, 2012.

unprotected or unmanaged rock art sites, where sites located on private property or specialized zones, such as Native American reservations, are commoditized and presented to the public with minimal oversight or damage control (Allen & Groom, 2013b; McDonald & Veth, 2012; P. Schaafsma, 1986)—leaving the resource at the mercy of tourist behavior, which is not always ideal (see Figure 2.4D)(Smith, 2016).

Unfortunately, there still exists an inherent divide between sustainable tourism development and rock art research/conservation—an issue desperately in need of future attention (McDonald & Veth, 2012; Whitley, 2001). Deacon (2006) explores the modern and historic tendency for rock art conservation and tourism efforts to "remain in opposing camps" (p. 379), as well as urging fellow scholars to expand scientific knowledge regarding the counter-intuitively symbiotic relationship between protecting the resource and exposing it to tourism. Her argument is based on the idea that the only way for rock art sites to accomplish self-sustained longevity is through balancing tourism income with resource impact (Deacon, 2006). In other words, while isolated/restricted rock art sites may be less anthropogenically degraded, they also lack the fund for any conservation efforts should the need arise. Tourism is becoming a ubiquitous global phenomenon and for rock art to continue to survive, integrated research on the complex relationship between tourism, landscape change, and cultural stone decay is critical (McDonald & Veth, 2012). User-friendly mixed field methods, such as those presented in this dissertation, present scholars from all backgrounds a less-intimidating way to begin bridging the informational gap that has limited holistic research of rock art tourism and cultural stone decay.

CHAPTER 3: METHODOLOGY

The often fragile nature of rock art and cultural stone landscapes inherently discourages traditional research methods, many of which are prohibitively invasive, time-intensive, or overly expensive, despite the invaluable information such studies could provide to improve conservation and management efficacy (Allen & Groom, 2013a; Cerveny, 2005; Whitley, 2001). To address this dilemma, the creation and validation of cost and time-sensitive non-invasive rock decay research methods to assess the physical conditions of cultural sites, built or natural, is paramount to their continued survival and viability as cultural and heritage resources. Several techniques have been developed over the years to research cultural stone decay, each exhibiting different strengths, weaknesses, and intended subject matter (i.e. buildings vs. rock art vs. natural landscapes). This chapter explores these methods and the larger scientific context in which they function before discussing specific techniques in greater detail and their applicability towards addressing cultural heritage management challenges. It is important to bear in mind the theoretical concepts of landscape and value of place examined in the previous chapter when addressing research methods and techniques for protected or culturally significant landforms and resources, where the boundaries between physical and cultural characteristics are more difficult to differentiate.

3.1 – EXISTING RESEARCH METHODS FOR CULTURAL STONE DECAY

In many cases, methods and techniques often used to assess cultural stone decay or rock art stability stem from the wider fields of geomorphology and rock decay (weathering) science. Therefore, before there can be any discussion on specific cultural stone decay research methods, it is first necessary to outline the wider academic context in which these techniques were developed. A brief summary of primary rock decay and landscape change theory and research methods is provided, followed by more focused reviews of existing research techniques applied to evaluate cultural stone and rock art deterioration. The two primary methods employed in this dissertation—the Rock Art Stability Index (RASI) and repeat photography (RP) are then explored in greater detail, including function, past applications, strengths and weaknesses, as well as their applicability to tourism management and research.

3.1.1 – Assessing Rock Decay and Landscape Change

The primary focus of geomorphologic research is to investigate the dynamic exchange of forms and processes constantly creating and transforming landscapes. Countless scholars have studied the Earth's physical features in attempts to better understand their surroundings and grasp intellectual concepts of processes operating well beyond the scope of human timespans. Greek and Roman philosophers, such as Strabo (ca. 64 BC – AD 20), Aristotle (384 – 322 BC), and Herodotus (484 – ca. 425 BC), contemplated the formation of landforms and changing landscapes, as well as speculating the primary agents impacting Earth's surface, in many cases, with remarkable accuracy (Martin & James, 1993). In more recent literature, significant geomorphologic research into landscape change has incorporated some form of empirical morphometric analyses, quantifying form and shape. These studies range from physically measuring surface recession (Inkpen & Jackson, 2000; Paradise, 1999) and investigating surface moisture as a geomorphic agent (Mol & Viles, 2012), to appraising specific dimensions and characteristics of decay (McBride & Picard, 2004) and examining detached weathering debris, such as grus and talus (Mustoe, 1983).

The tools and methods employed in these various geomorphologic endeavors are equally diverse. Geomorphologic and geometric research techniques can be as simple as measuring landscape features with standard tape measurers and/or calipers (McBride & Picard, 2004; Paradise, 1999) or as complicated as incorporating a slew of electronic equipment including velocimeters, anemometers, hydrophones, and profilers to calculate eularian flow measurements in fluvial or aeolian landscapes (Sherman et al., 2013). Even qualitative methods, such as time-lapse photography (Nichols et al., 2016) or the construction of conceptual models (Huang et al., 2014), have been used to assess landscape change and geomorphologic processes. As with many other fields of scientific inquiry, significant innovations in technology have been revolutionizing geomorphologic research. In a recent review of technology in geomorphology, Viles (2016) discussed the influx of previously unanswerable research questions scholars now have the ability to pursue with advancements in remote sensing, more precise dating techniques, and new applications in geophysical techniques. She also highlights how technology has encouraged more cross-pollination of scientific endeavors—integrating previously disparate disciplines in multidisciplinary investigations—as well as bringing field and computer/modeling analyses closer to each other (Viles, 2016). With such an arsenal of geomorphologic research methods, techniques are highly case-specific and it is up to the individual researchers to determine which is most appropriate for their specific topic.

Where geomorphology functions within a broader landscape scope, rock decay (weathering) investigations tend to be more focused specifically on the deterioration of stone, considered by most as the fundamental agent of landscape change (Dixon et al., 2009). Historically called *weathering*, rock decay processes are quite diverse and not solely dependent upon environmental influence, therefore, to distance stone *weathering* from *weather* many geomorphologists opt for the more appropriate term *rock decay* (Dorn et al., 2013; Hall et al., 2012). Similar to geomorphology, rock decay processes and patterns of deterioration exist within various geographical and climatological contexts, presenting researchers with a myriad of different variables capable of influencing decay (Moropoulou et al., 1995; Pope et al., 1995). This has lead to the establishments of environmental sub-fields within geomorphology and rock decay science, such as “arid geomorphology” (e.g. Parsons & Abrahams, 1994) or “tropical weathering” (e.g. Johnsson et al., 1991).

Even within the specialized field of rock decay, methods and research approaches vary dramatically. For example, explorations range from elaborate mathematical fractal models justifying a universal decay index (Oleschko et al., 2004) to artificially replicating the conditions in which salt wedging in sandstone would occur in hot deserts within a controlled laboratory setting (Smith & McGreevy, 1983) to detailed thin section analysis using phenocrysts as proxies for decay (Topal, 2002). Attempts have been made to classify rock decay using geo-engineering criteria such as joint factors and uniaxial compressive strengths (Ramamurthy, 2004), advanced geographic information systems (GIS)(Inkpen et al., 2001), or graphical representations of field observations on lithology, compressive strengths, and discontinuities (Palicki, 1997). While simulated experiments and models can present groundbreaking results, some scholars consider such studies “unrealistic” and promote *in situ* fieldwork as more reliable to determine how decay processes function in the real world (Dorn et al., 2013). This could include anything from applied field examinations to distinguish the impact of biological rock coatings and desert varnish on stone stability (Dorn & Oberlander, 1982; Staley et al., 1992) to collecting samples for intensive mineralogical geochemical and isotopic analyses to assess chromium depletion during rock decay in tropical environments (Berger & Frei, 2014). While the methods and techniques used to analyze and explore rock decay processes vary, both in application and scope, as much as wider geomorphologic techniques, the special characteristics of cultural stone complicates matters, simultaneously limiting and enhancing scientific research potential (Pope et al., 2002; Smith et al., 2005).

3.1.2 – Techniques in Cultural Stone Decay Research

The fundamental characteristics and traits of cultural and historic stonework presents scholars with unique, albeit challenging, research opportunities by providing information virtually impossible to determine for natural (non-worked) stone and involving various intersecting academic disciplines. Whether acknowledged explicitly (Mottershead et al., 2003) or contextually (Paradise, 2005), the intrinsic features of worked stone has prompted numerous advances in geomorphologic and rock decay science. Such advances have included identifying mineral thresholds impacting sandstone decay due to the existence of reliable estimated baseline surfaces (Paradise, 1999), known construction dates facilitating empirical validation of specific decay rate models (Sunamura & Aoki, 2011), and consistency of stone material and shape allowing assessments of environmental change in different locations (Inkpen & Jackson, 2000). One of the most significant features of cultural/worked stone is the stone's date of exposure documentation. This characteristic permits direct comparisons of rock decay in separate environments (Achyuthan et al., 2010), between stones of varying age (Mottershead, 1997), and multiple repeated assessments over time to quantify rate of change (Thornbush & Viles, 2008). In many cases, the validity of these studies' findings hinge upon the additional "control" provided by characteristics fundamental to cultural stone.

These studies are not without limitations, however. One such limitation is inherent context: the locale, number, and condition of cultural stone is predominantly limited to regions of human occupation—often excluding inhospitable locations such as hyper-arid deserts or Polar Regions, where human activity is usually scattered and/or semi-nomadic. Because of this, much of the existing cultural stone decay research focuses on the plentiful resources in humid, temperate, or coastal environments, with significantly less investigations in arid environments—despite the existence of spectacular desert settlements, such as Petra, Jordan. Potential cultural stone decay research must also respect numerous constraints and regulations dictated by the governing heritage management agency. Despite insistent entreaties to incorporate rock decay science in CRM (Burns, 1991), the protective character of heritage management bars most types of destructive or invasive research techniques. For cultural stone stability assessments, this restriction discourages the use of quite a few traditional geomorphologic methods, many requiring rock samples obtained via coring or rock hammers (Berger & Frei, 2014). One strategy to bypass these limitations is to conduct research on fresh samples of popular building stones, such as Warke and Smith (2007), who analyzed five different building stones for durability and decay vulnerability. While this study provided valuable information to current or future cultural stone constructions, its methods cannot be applied to pre-existing cultural stone. To meet the scientific need for stability assessment without disregarding protective policies, a number of non-invasive rock decay research techniques have been developed to specifically address cultural stone decay without compromising historic integrity and context (Smith et al., 2008).

Limited to non-invasive or observational analyses of extrinsic variables, research techniques designed for cultural stone decay are surprisingly diverse. Most often associated with historic buildings and quarried stone, many methods include some form of engineering focus or application (Přikryl & Smith, 2007). For instance, McKinley et al. (2006) used portable probe premeameter to assess stone permeability as a means to construct a geostatistical prediction model for decay. Such a model would be a powerful tool for building managers and engineers to more effectively mitigate future decay events. Alternatively, investigators focus on the distribution of decay features on the stone surface (e.g. Antill & Viles, 1998; Inkpen et al., 2001). This can be complicated, though, as many scholars use different terminology to describe similar decay forms and there lacks a universal rock decay vernacular (Doehne & Price, 2010; Groom et al., 2015). However, resources such as the ICOMOS *Illustrated Glossary on Stone Deterioration Patterns* (Vergès-Belmin, 2008) help provide scholars with universal definitions and terms to help lessen terminological discontinuity. In some cases, scholars have even combined multiple research approaches and techniques to better address the complex challenges and limitations of cultural stone decay research. For example, McCabe et al. (2007) paired spatial mapping of decay features and an observational rock decay staging system to construct a more holistic approach to assess building stone stability.

As with geomorphologic research, technology has also played an integral role in advancing cultural stone stability knowledge and investigation opportunities. Supplementing traditional photographic assessment of rock decay, new developments in photographic manipulation software have allowed researchers to construct digital 3D models of fragile cultural stone features using a method known as polynomial transform mapping (PTM)(Malzbender et al., 2001) and more accurately analyze minute surface changes via detailed time-lapse photography (Doehne & Pinchin, 2008; Sawdy & Heritage, 2007). Technical tools such as ultrasound have been adapted to detect miniscule cracks, voids, and other anomalous features in cultural stone surfaces (Böhm, 2004; Doehne & Price, 2010), as well as evaluate the effectiveness of conservation efforts and stone treatments (Favaro et al., 2007; Simon & Lind, 1999). Another emerging tool for cultural stone decay is ground penetrating radar (GPR), which is being used to identify flaws, weaknesses, or voids within historic stone structures (Binda et al., 2003; Palieraki et al., 2008) or other forms of cultural stone (Huneau et al., 2008). Even basic field observations have benefited from technological developments: Trudgill et al. (2001) employed optical profilometry, essentially projecting a laser grid perpendicular to the stone surface and documenting irregularities in surface texture. While a few of the discussed cultural stone research techniques can be applied to rock art stability assessments (e.g. Huneau et al., 2008), additional constraints and inherent characteristics of rock art sites often requires a more tailored approach.

3.1.3 – Methods for Rock Art Research and Conservation

Despite the various tools and techniques devised to evaluate various aspects of cultural stone decay and site stability, very few are suitable for assessing rock art and even fewer are specifically designed for that purpose. With the vast majority of rock art investigations focused on archaeological/content significance or dating techniques (Whitley, 2001), rock art stability and deterioration research is under-represented in the stone conservation and CRM fields (Dean et al., 2006). This is often reflected in educational material, such as Wiley's *A Companion to Rock Art* limiting rock art decay research and conservation methods to a handful of paragraphs in the opening chapter (McDonald & Veth, 2012). This is not to say rock art decay research methods do not exist, just that they are limited compared to the wider fields of geomorphology and cultural stone decay. Within rock art research (beyond anthropological studies), foci and techniques tend to fall within two main categories: documentation of motifs and decay features and identifying the most immediate threats.

With hundreds of thousands of known rock art sites around the world (Clottes, 2006), documentation is among the earliest and most approachable rock art research techniques for assessing site stability (Doehne & Price, 2010; Larkin, 2002; Padgett & Barthuli, 1997). Methodology for documentation is highly diverse, ranging from simple descriptive and photographic records (Barnett et al., 2005) to complex digital measurements and post-field photo-manipulation (Clogg et al., 2000; Huneau et al., 2008). In some cases, documentation of panels and observed decay features is accompanied with minimally invasive sample collection for further analysis in a lab (de Oliveira Castello Branco & Souza, 2002) or within the framework of condition/decay indices (Duzgoren-Aydin et al., 2002; Warke et al., 2003). Advancements in computer-enhanced image processing has also prompted new studies incorporating 3D imaging into the documentation of rock art sites and decay features (Simpson et al., 2004; Trinks, 2005; Wasklewicz et al., 2005), although this is not always without complications. Díaz-Andreu et al. (2006) exemplify how over-reliance on technology can limit discovery when their detailed 3D laser scan failed to detect a spiral motif visible in a rubbing of the same panel made ten years earlier. The value of documentation can also go beyond the physical features of rock sites. For example, Clottes (2008b) explores the merits of not only preserving rock art but also the cultural and historical context in which the images exist. He argues how the stories of the artists and their decedents, oral histories, and other intangible heritage associated with rock art are just as important as the features themselves—that one gives context and meaning to the other so both should be recorded (Clottes, 2008b).

While documentation is the most common research approach to rock art stability (Doehne & Price, 2010), others focus on identifying the most immediate threats or the impacts of specific decay processes. The methods and techniques employed in these studies are highly case-specific and vary significantly depending on the target research topic or concern. These range from using lead and strontium isotopes to determine the impact of pollution and road proximity on Norwegian petroglyphs (Åberg et al., 1999), and geochemical analyses of lichen-stone interactions in relation to rock art stability (Dandridge, 2006), to XRD and SEM examinations of pictograph pigments and in-situ temperature readings as means to assess microclimate influences on rock art decay (Hall et al., 2007; Hœrlé, 2006), and employing a battery of laboratory imaging technologies, including optical microscopy, backscattered electron microscopy, x-ray, and high-resolution transmission electron microscopy, on selected petroglyph and adjacent stone samples to investigate the effect of wildfires on rock art decay (Tratebas et al., 2004). Even scholars researching the same decay agent have approached the issue from different directions. For example, Kloor (2008) used repeat photography to showcase the aesthetical impact of dust coatings obscuring motifs where Watchman (1998) was more interesting in determining the composition of dust coatings affecting rock art stability. With the growth of global tourism, some scholars have shifted focus to address the impacts people and visitation on rock art sites employing assorted methods ranging from empirically monitoring rock shelter microclimate changes due to human activity (Hoyos et al., 1998) to more sociological investigations of perception, history, and management of rock art tourism (Deacon, 2006; Smith, 2006). Many of these papers end with some form of conservation suggestion going into the future—the testing of these being the third major rock art stability research theme.

Additionally, some scholars have advocated for applying research methods designed for historic worked stone, such as monuments and buildings, to assess rock art (e.g. Ashurst & Dimes, 1998), but key contrasts in scale, perception, and resources limit the applicability of such an approach (Doehne & Price, 2010). For instance, since the majority of building materials have documented dates of exposure (i.e. age of the building) and quarried stones are usually "raw" without previous signs of decay, most research methods created to assess worked stone incorporate an assumed baseline—a feature exceedingly more difficult to identify for rock art (Dean, 2001). Thus, adapting building-stone methods for rock art runs the risk of misinterpreting preexisting decay features on the host stone prior to application of the rock art, a characteristic known as "inherited weathering" (Battiau-Queney, 1996; Dorn, 2006). In addition, practitioners of architectural stone conservation generally regard rock coatings as harmful and agents of decay (e.g. Smith et al., 2005), but some coating are beneficial and even vital for the creation of petroglyphs (Dorn, 2009). Even more fundamental, a large portion of rock art condition assessments are carried out by students, volunteers, and citizen scientists due to limited resources compared to the vast number of rock art sites that exist around the world (Chandler et al., 2007). While well intended, these volunteers usually lack the technological or professional experience common among cultural stone conservators and other practitioners necessary to successfully employ more intensive cultural stone decay analyses and intervention/preservation techniques (Doehne & Price, 2010).

Such diagnostic techniques have the ability to improve scientific understanding of how rock art changes over time, but most are too costly, tedious, invasive (e.g. removal of samples), or require specialized training and/or practical knowledge—making such research inaccessible to many rock art sites with limited funding and personnel. There is little doubt that empirical investigations of rock art and cultural stone provides valuable information to both the geomorphological and cultural resource management communities (Pope et al., 2002), but for most protected rock art sites, the costs do not outweigh the benefits. However, the world's rock art continues to decay regardless of management efforts. For rock art sites functioning with limited resources, the development and implementation of cost-effective, non-invasive, and approachable research methods are critical to the rock art's prolonged survival. As many rock art research techniques are adapted from other fields, such as oncology (Warke et al., 2003), perhaps new emphasis should be placed on incorporating rapid field assessment techniques into the investigation of rock art deterioration and, ultimately, protection—methods such as the Rock Art Stability Index and repeat photography.

3.2 – ROCK ART STABILITY INDEX (RASI)

Designed by a multidisciplinary team of conservators and specialists from various backgrounds—i.e. rock decay science, rock art, CRM and conservation, geo-education, and GIS—the Rock Art Stability Index (RASI) is a user-friendly field index that can be used to quickly assess the physical condition of rock art panels—integrating past decay events, current issues, and potential concerns into the near future (Dorn et al., 2008). Considered a rapid field assessment technique, the purpose of RASI is to provide a cheap, dependable tool that rock art conservators can employ with minimal required training (two day workshop) and a handful of volunteers (Cerveny et al., 2016). While more strenuous and precise rock decay research techniques exist (e.g. Fitzner, 2002), the accessibility and practical merits of RASI make it a powerful research tool for management, education, and under-funded/developing sites. The functionality of the index, along with its strengths and weaknesses, will be discussed before exploring its applicability towards tourism and rock art management.

3.2.1 – Function and Application

Featuring six overlying categories, the Rock Art Stability Index (RASI) incorporates nearly three-dozen distinctive rock decay forms/processes to determine the current physical status of rock art panels (definable stone surfaces with discrete concentrations of rock art features), along with estimated future threats. Users of the index mark the severity of each decay form on a discrete scale of zero to three, with each value observationally defined: 0 = non-existent on the panel, 1 = present but detrimental to the rock art, 2 = obvious and initiating problems, and 3 = dominant and/or directly damaging the rock art. Practitioners learn to distinguish the differences and thresholds between each value during the training workshop. The individual form scores, valuable in and of themselves, are totaled to generate an overall panel score (maximum = 100). Since larger values on the index scale denote more advanced decay, lower final panel scores indicate a greater degree of stability (Figure 3.1). RASI panel scores can then be used to quickly establish which panels are in most need of intervention, whether conservation/restoration or documentation before the rock art deteriorates beyond recognition. For additional administrative ease, score ranges are separated into six different descriptive classifications:

- *≤ 20: Excellent Condition*
- *20 – 29: Good Status*
- *30 – 39: Problem(s) that Could Cause Erosion*
- *40 – 49: Urgent Possibility of Erosion*
- *50 – 59: Great Danger of Erosion*
- *≥ 60: Severe Danger of Erosion*

To aid volunteer training and correspond with geomorphologic and rock decay literature, RASI's six overarching categories are organized thus: site setting (geologic setting), impending loss (intrinsic weaknesses), large break-off events, incremental loss (small erosion events), rock coatings and deposits, and vandalism and other issues. "Site setting" evaluates the panel's geologic and contextual factors (e.g. fissures/joints, lithological anomalies, stone hardness). "Impending loss" assesses weaknesses and evidence of potential future decay (e.g. weathering rind development, fissuresols). "Large Break-off events" catalogs larger (~meso-scale) detachment or decay events (e.g. anthropogenic removal of material, undercutting/rock fall). "Incremental loss" reviews smaller (~micro-scale) rock decay and superficial issues (e.g. diminishing rock coatings, splintering, flaking). It is worth noting that cm- and mm-scale stone decay processes abound. This is reflected in RASI, with considerably more decay types in incremental loss than any other category. Features in the "Rock Coatings" are unique, as, in some cases, rock coatings can actually help stabilize rock art sites (Dorn, 2009). Consequently, half the forms represented in the rock coatings section utilize negative values (i.e. 0, -1, -2, -3), working to lower the final score. RASI also includes a sixth, descriptive category (vandalism and other issues) that does not contribute to the final score but permits volunteers a place to document important field observations or personal concerns—which can be helpful when interpreting finished RASI scores. Together, these categories culminate in a broad, yet comprehensive, assessment of various decay features and the processes behind them, all within a single field index (Dorn et al., 2008)(Examples of completed RASI sheets can be found in Appendices B and D). Until recently, RASI has been predominantly limited rock art but new innovations adapted the index to assess all forms of stone heritage, including monuments and/or building facades, with the Cultural Stone Stability Index (CSSI). A deeper discussion of this adaptation will take place in Chapter 6 and visual comparisons of RASI and CSSI are displayed in Appendix G.

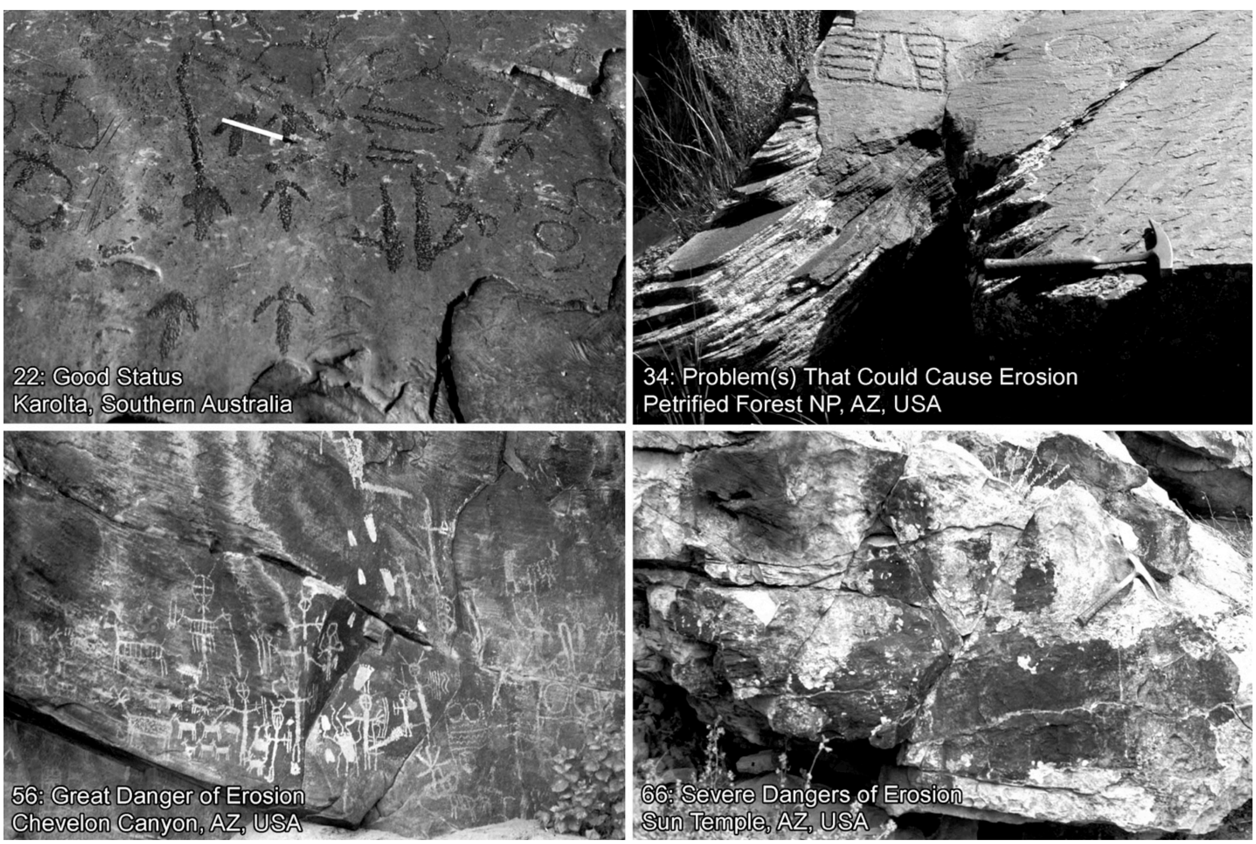


Figure 3.1: Examples of rock art panels with various RASI scores displaying the diverse conditional and decay features addressed in the index. All photos from the online RASI Atlas (Cerveny et al., 2007).

3.2.2 – Strengths and Limitations

The range of decay processes incorporated in RASI analyses is one of its strongest assets as a scientific tool: not only do researchers rate the severity of rock decay but also determine the processes responsible. With rock art research scholars so often hyper focused on only a handful of decay agents, many risk neglecting the multitude of interconnecting geomorphologic processes driving rock decay. There is never just one factor impacting rock art deterioration (Whitley, 2001). Alternatively, investigations seeking to identify every single decay process impacting a particular panel have entailed measuring more than twenty different field metrics and over forty rigorous laboratory analyses on collected stone samples requiring extensive funding and research equipment (Fitzner, 2002). Scientific research indices, such as RASI, help avoid overly-complicated/costly empirical approaches while still addressing multiple different potential rock decay processes. There have been other indices developed to assess cultural stone stability, but these are either unnecessarily complicated (Warke et al., 2003) or still too focused on specific processes (Duzgoren-Aydin et al., 2002). The general breakdown of RASI into the six main themes ensures representative decay processes from each primary source of decay, whether from larger intermittent events, slow-but-steady wear, or the manifestations of internal weaknesses—only requiring brief field examinations.

Not only is RASI relatively comprehensive, it is also fast with assessments only requiring minutes per panel. Final reports with RASI interpretations and score averages can be prepared immediately following fieldwork, helping heritage management agencies more effectively implement new policies or identify panels in critical condition without risking further deterioration while data is being processed. For example, RASI’s rapid application allowed ten students/volunteers to score over two-dozen individual rock art sites and nearly a thousand individual panels during a two week research project at the Petrified Forest National Park, AZ (Groom & Thompson, 2011). When paired with instantaneous global positioning systems (GPS) technology, RASI can easily be integrated into geographic information systems (GIS) for even more detailed spatial analysis to reveal distributional patterns and influences on decay (Allen et al., 2011). RASI scores expressed visually via GIS or cartographic output can further help disseminate rock art stability and rock decay knowledge to non-specialists and/or site management.

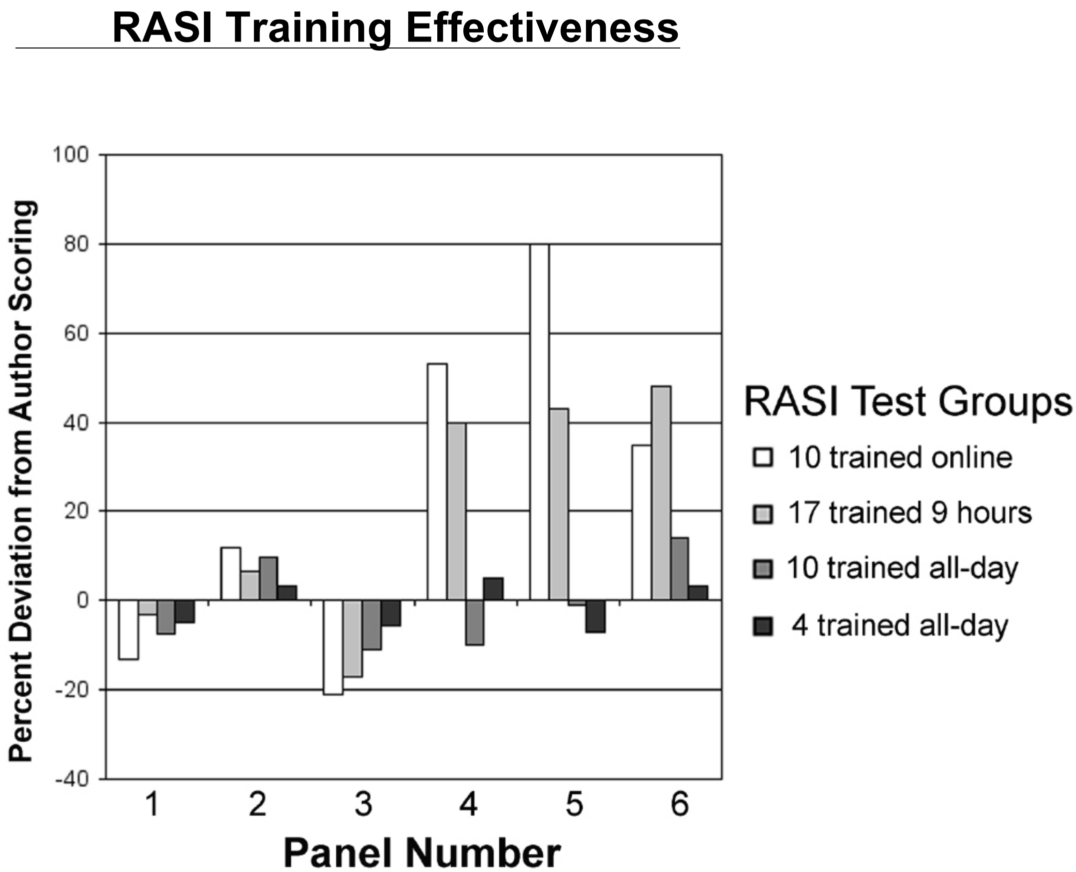


Figure 3.2: Graph displaying the efficacy of RASI training in relation to number of students and teaching format. Smaller groups (shown in the darker grays) in person training sessions show the lowest degree of deviation in final RASI scores. Graphic from Dorn et al. (2008, p. 60).

Designed to meet the needs of any rock art site, despite monetary or personnel resources, RASI intentionally lacks technical jargon and overly expensive training processes—increasing accessibility to non-specialists volunteers and site managers. Because the index is observationally based, volunteers can identify and rate each rock decay form without needing to know the underlying processes creating them. After the scores are recorded, it is fairly simple for a specialist to interpret RASI scores in more detail at a later time, if required. The ease of the index permits local management and/or conservation volunteers to personally participate in site evaluation—an option not usually possible with other more-traditional research methods. Direct involvement with scientific research and conservation assessments with RASI can help increase management awareness of rock decay processes and promote a more personal connection with the status of the rock art (Allen et al., 2011). Not requiring intensive long-term training or laboratory equipment also substantially reduces research costs, often a significant limitation for rock art management. The only recourses required are willing volunteers, an expert to train them, and pen and paper—all the while presenting timely, informative assessments with minimal cost and avoiding sample collection or damaging the rock art panels.

The accessibility of RASI to non-specialist volunteers, while a true benefit of the index, also puts limitations on one of RASI's greatest strengths: replicability. Because the index functions on allowing non-specialists to actively participate in data collection, research credibility and scientific replicability is highly dependent on the quality of training. When introducing RASI, Dorn et al. (2008) presented different training options and the resulting replicability of RASI scores based on four focus groups, each using a different method of training (Figure 3.2). They found online or too short of training sessions yielded dramatically more varied RASI scores and poor replicability, where all-day trainings with smaller groups (4-10 volunteers) are more conducive to delivering more reliable replicable results. Therefore, extra emphasis should be placed on training prior to any application of RASI and only experts in the index are qualified to provide the level of training necessary to retain RASI's reliability and replicability as a scientific tool.

3.2.3 – Applicability for Rock Art Tourism Management

The application of RASI in rock art tourism is relatively self-apparent: the index was specifically designed as an educational and management tool to aide in the conservation and effective management of inherently fragile rock art landscapes (Dorn et al., 2008). Exemplifying this function, RASI was the primary technique employed during a 5-year project funded by the National Science Foundation (NSF) to survey thousands of Native American petroglyphs in the Petrified Forest National Park, AZ (Dorn et al., 2013). A major focus of this project was to determine the stability of sites regularly visited—and unfortunately damaged—by tourists: panels adjacent to hiking trails, roadways, near Hopi Native American sacred sites (Groom & Poole, 2010; Groom & Thompson, 2011), and even the condition of historically significant graffiti (Groom, 2011). The accessibility of RASI allowed National Park personnel to take part in the assessments and witness first-hand the condition of their resources. Final reports from this project helped influence park management decisions by discouraged guided tours to a particularly fragile site previously considered stable and criticized the proposed opening of a marginal site to visitors, while also suggesting several potential replacement sites in significantly better condition (Groom & Poole, 2010; Groom & Thompson, 2011). In addition to the US Southwest (Allen & Lukinbeal, 2011), RASI has also been employing in the US South (Groom, 2016), Caribbean (Allen & Groom, 2013a, 2013b), and Middle East (Groom, 2016c).

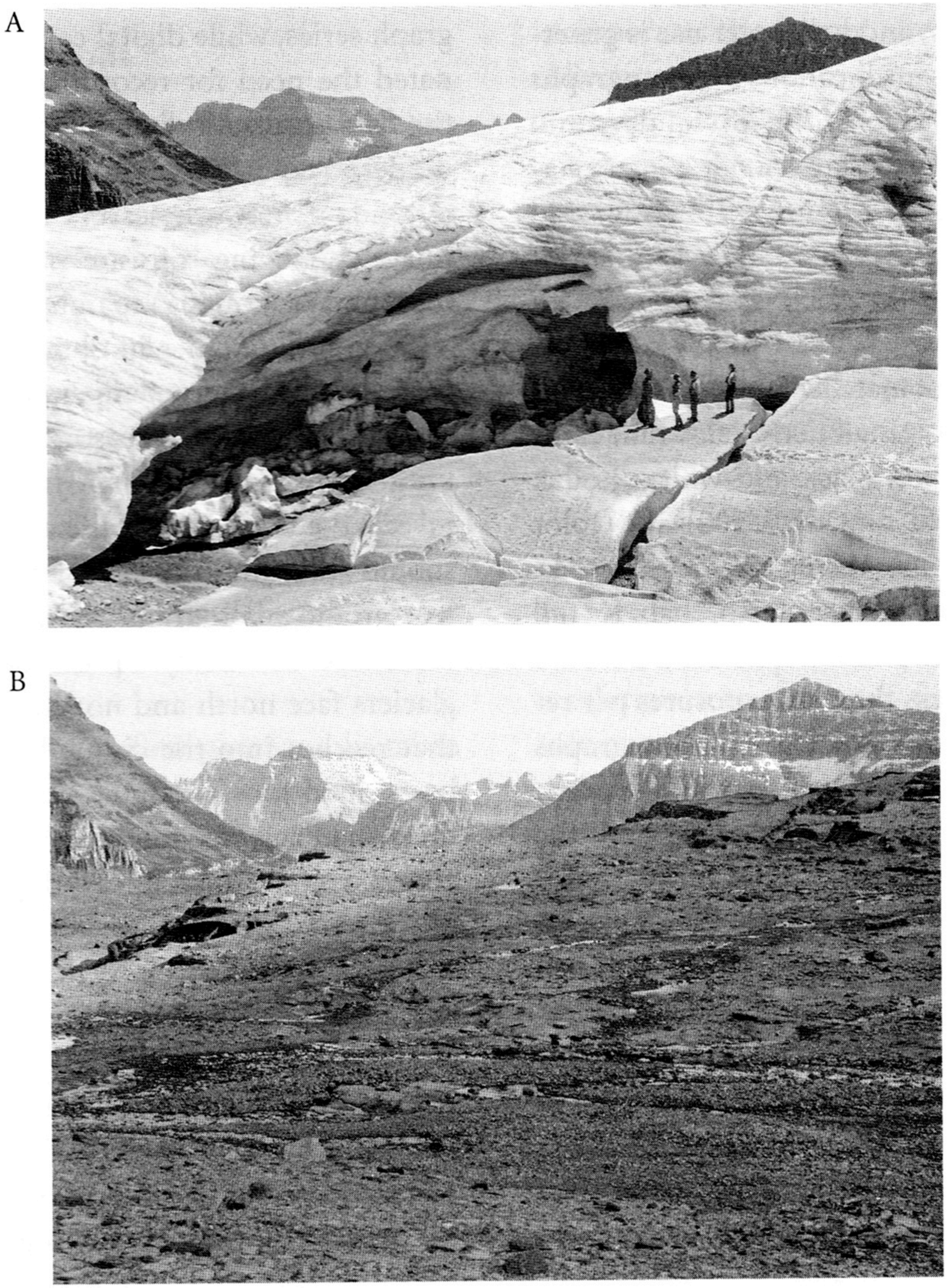
As the tourism industry continues to expand, rapid non-invasive assessment tools, like RASI, will become even more critical to CRM efforts and rock art conservation—maybe even in more unconventional ways. Since rock art research usually depends so heavily on volunteers, perhaps increased tourism could somehow benefit site stability research. Because RASI is intentionally user-friendly, it could potentially be used not only to assess the impacts of tourists but those tourists could be directly involved in that assessment. Conservation tourism, a sub-genre of eco-tourism, revolves around the concept of visitors paying to participate in some form of conservation effort, usually ecological or zoological in nature (Buckley, 2010; Cousins, 2007). As stated by Whitley (2001), "There has always been a large public interest in ancient pictures painted or carved on stone…" (p. 1), so why not harness that interest via conservation tourism? Many scholars have stated the best method of protecting fragile cultural tourism resources is through community engagement and education (du Cros & McKercher, 2015) and Allen (2008) found that RASI helped students engage with the resource and better retain rock decay knowledge compared to traditional pedagogy—why not pair the two? Rock art volunteer groups already exist, such as the American Rock Art Research Association, but many "conservation efforts" conducted by these entities have actually caused more damage than good (Dean et al., 2006; McDonald & Veth, 2012; Whitley, 2001). By introducing dedicated (ideally self-funded) volunteers with a non-invasive reliable research technique, RASI could potentially bridge the gap between tourism and rock art management. Of course, there are some limitations and concerns with this approach, such as uncontrolled growth or counter-productive research efforts (du Cros & McKercher, 2015), and further research would be required prior to any form of implementation.

3.3 – REPEAT PHOTOGRAPHY

Providing visual representations of change over time, repeat photography, sometimes called rephotography, has become a valuable and versatile research tool in the social and physical sciences (Smith, 2007; Webb et al., 2010). Emerging shortly after the invention of photography itself, repeat photography was first employed in 1888 as a means to monitor glacial advancement and retreat in the Alps by Bavarian mathematician Sebastian Finsterwalder (Hattersley-Smith, 1966). The success of this original research inspired other similar works and repeat photography became a well-established tool in glaciology still in use today to evaluate glacier activity (Byers, 2007; Fox & Cooper, 1998). The flexibility of repeat photography also promoted adaptations and the technique quickly reached other physical disciplines such as geology (Bryan & La Rue, 1927), geomorphology (Lobeck, 1939), and ecology (Clements, 1905). Extending beyond the physical sciences, repeat photography has also been proven useful in assessing social and cultural features such as determining the socio-economic influences of tourism on built infrastructure (Finn et al., 2009) and changes in land-use and development (Kull, 2005). Even more esoteric, the technique has been employed by anthropologists to visualize collective sense of place and communal awareness (Smith, 2007). Closer to the research at hand, repeat photography has been a common tool for informally monitoring rock art sites for several decades but there is significant room for technical applications, with more rigorous repeat precision standards and post-field digital analyses, to further scientific understanding of rock art decay and conservation (Loubser, 2011).

3.3.1 – Function and Application

As the name indicates, the basic concept of repeat photography is the comparison of existing and new (repeat) images captured from the same perspective, necessitating detailed matching of angle, elevation, and aspect. The time period between the images is case-specific and can range from yearly repeats to replicating decades or even centuries old historic photographs (Webb et al., 2010). The time interval between photographs provides a temporal context for any change visible between the repeated pair, which can be quite dramatic. For example, McClaran et al.'s (2010) quasi-decadal photographic monitoring of the Santa Rita Experimental Range (SRER) in Arizona allowed them to interpret the temporal and special characteristics and dynamics of desert grassland vegetation and landscape change



Glacier Ice Cave, Glacier National Park, Montana, USA.

Figure 3.3 – Example of repeat photography in glaciology. This particular graphic shows the change of the Glacier Ice Cave from A: 1932 to 1988. Photos by G.A. Grant and J. DeSanto in Fagre and McKeon (2010).

in a marginalized environment. On the other end, repeat photography comparing historic and modern landscapes are also valuable, such as the National Park Service's historic repeat photography project identifying changes in glaciers in Glacier National Park in Montana, which display a startling recession and disappearance of many park ice masses (Figure 3.3)(Fagre & McKeon, 2010). Beyond temporal ranges, depending on the purpose of the study and quality of existing photos, techniques for finding image positions and insuring repeat accuracy, along with post-field analyses, vary considerably.

Largely study-specific, several techniques exist for locating the correct vantage point—also called camera stations—each with their own pros and cons. Some scholars may attempt to promote a "best-practice" technique but, objectively speaking, there is no one superior method, as most are highly dependent on study location, camera technologies, and the primary purpose of the research (Boyer et al., 2010). Commonly used site identification methods range from employing parallax principles through pinpointing cross lines between photographic subjects in the foreground versus the background (Malde, 1973) to adapting advanced geospatial technologies such as remote sensing and digital photogrammetry (Hanks et al., 2010). However, the most popular technique—arguably due to its simplicity and accessibility—is the Brute-Force Technique, which involves locating distinctive photographic landforms in the field and attempting different vantage points until the researcher "walks into the view" (Boyer et al., 2010). This method may be among the easiest ways to replicate photographs, but repeat accuracy and precision are more difficult to ensure—which can be a major issue depending on research goals and requirements for post-collection analyses.

Similar to vantage point identification, there is an array of different repeat analysis techniques depending on the intended outcomes and desired information. Sometimes dismissed by the hard sciences as being too subjective or qualitative, the most common analysis is a simple visual comparison and description of significant differences between historic and repeat photographs. While certain criticisms of this method are true, identifying observational variation in the landscape can still be a powerful and useful tool for management and supplemental studies (Webb et al., 2010)—and in some cases visual comparison is all that is needed (Loubser, 2011). That said, advancements in digital processing technologies have allowed for more analytical approach to assessing landscape change. For example, with accurate enough repeats, researchers can overlay the two photographs in geo-processing software, such as GIS, to quantify change by pixel (Hoffman & Todd, 2010) or perform tedious photogrammetric calculations and computer modeling to determine precise areas and intensity of change (Hanks et al., 2010). Regardless of the more detailed and empirical results, attaining the necessary repeat accuracy and intimate knowledge of geo-processing technologies for these kinds of analyses can be prohibitive to resource-limited agencies.

3.3.2 – Strengths and Limitations

Repeat photography has proven itself to be a very useful research and management tool for several reasons. Among the most advantageous features of the technique is its ability to more holistically assess the collective landscape instead of hyper-focusing on just one aspect or variable of change. Where geomorphologists might only evaluate rock decay or physiographic alterations with a certain disregard for cultural features or anthropologists might study the impact of socio-economic shifts with little consideration for the physical impacts of such actions, repeat photography has the potential to capture both. This is particularly useful in culturally sensitive areas where both natural and human agents have influenced landscape change. Heritage management issues such as natural and/or anthropogenic rock decay, vandalism, impacts of tourism and land use, even beneficial changes like the erection of fences or restoration can all be monitored and analyzed with repeat photography. This can offer a more realistic representation of change, as many influences—human or otherwise—are not necessarily exclusive or independent from each other and researching only one element within the landscape risks neglecting other equally significant features or processes. Repeat photography simply shows the landscape as it was and as it is now, regardless of the reasons behind that change—which is particularly useful for areas with strong heritage or cultural significance. For such culturally protected sites, like national parks or archeological ruins, this objective and more holistic technique for assessing change can be an immensely helpful supplemental tool for any conservation or monitoring agendas by providing additional information often overlooked by conventional or overly specialized studies. Additionally, proper documentation of located repeat sites helps facilitate future studies and long-term monitoring of change (Boyer et al., 2010).

However, as with any method, researchers wishing to employ repeat photography must contend with a number of inherent limitations. The most fundamental restriction is photo accessibility and

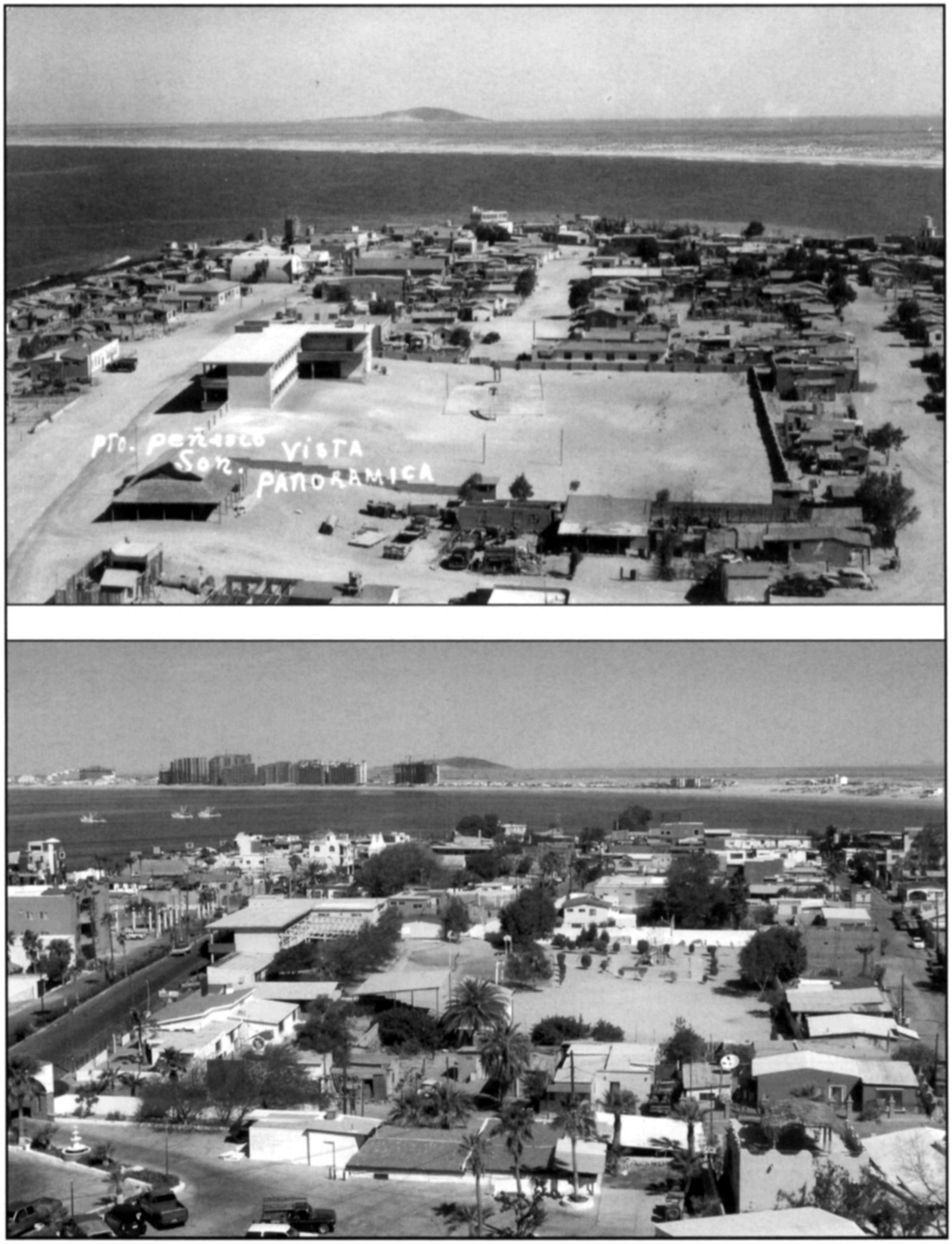


Figure 3.4: Repeated photographs of a small residential area in Puerto Peñasco. A small schoolyard and church are visible in the center of both photos. Major developments include improvement of roads and the construction of large resorts and condominiums in the background on the other side of the water. Vegetation and general infrastructure also show advancements. Images from Finn et al. (2009).

distribution: repeat photography is only a viable option where previous photographs exist—whether historic archives or resent collections. For example, finding quality photographs of remote or under-researched regions can be difficult and/or overly time-consuming. If there are no images to repeat, base line photographs are taken and researchers must wait the desired time period to repeat the first batch of images and finish the project (e.g. Hall, 2002). While this approach bypasses the need for pre-existing photographs, it can be problematic if scholars wish to assess long-term change. What is more, the mere existence of photographs is not enough for repeat photography to function—there are certain content requirements as well. Image quality, clarity, and distinctiveness are critical to correctly identifying to location of the image in the field and to provide any kind of meaningful analysis. A degraded or out of focus photograph would be prohibitively challenging to locate and assess. Graininess and distance from the targeted subject can also limit options for post-field analyses—e.g. smaller changed would he harder to identify if repeats were limited to wide angle landscape shots or poor quality images. Similarly, the content of the image must be recognizable, preferably with distinct features in both foreground and background to provide perspective (Boyer et al., 2010). Without such features, researchers risk repeating the wrong landscape—mistaking one indiscriminant tree or hill for another—thus nullifying any analysis and rendering their entire study useless.

Another component of repeat photography that can cause problems is the evolution of photographic technologies. Through the decades, technologies have advanced tremendously and with those changes, the processes by which images are captured, processed, and projected influence the final appearance of the photograph. Since photography is essentially a 2-dimentional portrayal of a 3-dimenstional space, certain distortions are inevitable. Similar to the various projections in cartography, features of photographic technologies, such as focal length, film material, image capture size, even digital versus film, alter the degree of distortion in the final product. When comparing modern photographs, which were most likely captured with a modern camera, to historic images taken with less advanced technologies, the differences in distortion must be addressed (Boyer et al., 2010). Advancements in virtual image processing software, such as Adobe® Photoshop™, may reduce the impact of technology gaps by allowing modern images to be manipulated to match the historic photos or even use a filter that replicates historic photograph appearances and distortion (Hanks et al., 2010). In addition, historic images are often grey-scale—minimizing researchers ability to assess changes in color or specific rock coatings or identify lithobiont species. Extra care must be taken when comparing color photographs to grey-scale or sepia images to avoid misrepresenting the sources of change. Even when comparing two grey-scale images, contrast and other photographic qualities influenced by advancements in technology should be addressed and acknowledged during evaluation.

3.3.3 – Applications for Rock Art and Tourism Management

In terms of global tourism, only a few studies have used repeat photography to assess change, though it shows great potential within this ever-expanding industry and field of research. In one of the earliest applications of repeat photography to study tourism dominated landscapes, Byers (1987) repeated historic photos from 1955-1963 explorations of the Khumbu region of the Himalaya Mountains. Over the decades, the area experienced considerable tourism development, initiating significant landscape change—change highlighted in Byers's study supplemented with intensive ground-truthing. More recently, Finn et al. (2009) employed repeat photography to identify socio-economic impacts of tourism via infrastructure and landscape development in Puerto Peñasco, Mexico: a small fishing village turned tourism hub within decades (Figure 3.4). Repeat photography has also been employed to assess more specific impacts of tourism, such as ecological changes and loss of biodiversity within historic sites (Moseley, 2006) and the visual influences of excavation, restoration, and stabilization on touristed archaeological sites (Howard et al., 2006)—a topic discussed in Chapter 6. While repeat photographic assessments of tourism are still relatively limited, they represent the potential of repeat photography in tourism studies and the immense capacity for future development.

More specific to rock art, repeat photography has been casually employed to identify changes in rock art appearances (Loubser, 2011), but it is still in its infancy within rock art tourism and cultural resource management. It could be argued that, as with other forms of cultural stone, aesthetics and visual quality of rock art is equally as important as physical stability in terms of its value as heritage and cultural resources (Heyd, 2003). For example, rock art that has experienced significant repatination—a process greatly beneficial to petroglyphs (Dorn, 2006)—can become quite difficult to see, potentially diminishing their usefulness for tourism or popular visitation. This, in turn, may lead local communities heavily dependent upon tourism to intervene and alter the stone surface to make the motifs more visible at the cost of panel stability. An example of this phenomenon is presented in Chapter 5. Repeat photography, fundamentally focused on visual quality, is then an appropriate tool to monitor aesthetical change of rock art and/or cultural stone resources within a managerial context. The visual impact of conservation and quality concerns such as vandalism, litter, or even repatination, can be identified through repeat photography separate from, but complementary to, empirical assessments of site stability and physical conditions—a relationship examined in the next chapter.

CHAPTER 4: CASE STUDY #1

Mixed Rapid Field Assessment Techniques in Rock Art Conservation:

Multi-Method Analysis of Rock Art in the Arkansan Ozark

4.1 – INTRODUCTION

The Ozarks of Arkansas are home to countless stunning historic and pre-historic rock art sites that are, unfortunately, at risk of disappearing forever. Cultural sensitivity and legal regulations surrounding significant rock art sites often limit traditional rock decay research methods, many requiring fairly lengthy and invasive procedures, despite the benefits such scientific analyses could provide heritage management efforts (Allen & Groom, 2013a; Cerveny, 2005; G.A. Pope et al., 2002). In attempts to bridge the divide between rock art research and conservation, a number of non-invasive rock art analysis techniques have emerged. The summary of these methods presented in Chapter 3.1.3 highlighted the strengths and weaknesses of non-invasive or minimally invasive rapid field assessment (RFA) techniques, but what if complementary methods were applied in tandem? Would the strengths of one method supplement the weaknesses of another? To address this question, this case study explores the merits of combining the Rock Art Stability Index (RASI), which provides valuable quantitative information about contemporary decay forms and processes but lacks temporal depth, and repeat photography, which assesses visual change over time but only within a limited observational/qualitative framework.

To best assess the applicability of this mixed method approach, the paired methods were applied at three distinctive archaeological sites in the Arkansan Ozarks composed of different lithologies, rock art type (i.e. pictographs, petroglyphs, and a combination of the two), management policies, and physical geographic landscapes. The three sites not only provide various contexts in which to test the effectiveness of the mixed-RFA approach, but are also representative of the diversity found within the Arkansan Ozarks: The Narrows, Putnam, and Edgemont Rock Shelters (Figure 4.1). To discourage looting or site disturbances, common issues often following archeological discoveries, site locations and key details will remain confidential. Also influential in site selection was the existence of early photographic records curated by the University of Arkansas Museum and the Arkansas Archeological Survey (AAS), a fundamental necessity for repeat photography analyses. However, before results and analyses of the case study are discussed, an exploration of the historical, physical, and research contexts of rock art in Arkansas is provided.

4.1.1 – Site Setting

The state of Arkansas, located in the south central United States, boasts a characteristically dynamic landscape and regional history. The state's physical topographies range from foggy mountain peaks and densely wooded valleys, or "hollers", to sprawling fertile floodplains and dramatic limestone cliffs outlining lazy rivers. With the variety of the region's landscapes and natural resources, it is no wonder Arkansas has earned the moniker "The Natural State". Variations in landscape characteristics such as elevation, vegetation, and environment divide Arkansas into six distinctive ecological regions: the Ozark Plateau, Arkansas River Valley, Ouachita Mountains, Crowley's Ridge, Mississippi River Delta, and Coastal Plain (Paradise, 2010)(See Figure 4.1). Each region boasts unique and striking landscapes and physical features, however, the rock art examined in this study are concentrated on the Ozark Plateau, so only this physiographic region will be explored in greater detail.

The Ozark Plateau, sometimes called the Ozark Highlands, is large and complex interstate uplifted physiographic region extending beyond Arkansas to also cover parts of Missouri, Oklahoma, and Kansas (Figure 4.2). Covering nearly 47,000 square miles (122,00 km^2), the Ozarks are credited as the largest mountain range between the Rocky and Appalachian Mountains (Paradise, 2010). However, the Ozark Plateau is actually composed of multiple ranges, the Boston Mountains being the most prominent in Arkansas, intersected by various rivers and uplifted valleys. The Buffalo National River, the first national river managed by the U.S. National Park Service, is one such river that flows unimpeded through the Ozark-St. Francis National Forest in north central Arkansas (NPS, 2016). With significant limestone deposits, this region exhibits intricate cave systems that are home to a number of endangered and threatened cave-dwelling animal species, including several bats, fish, and amphipods (T.R. Paradise, 2010). Beyond the caves, the Ozark's dense forests house a variety of hardwoods, such as numerous species of oak, hickory, sweetgum, maple, elm, and sycamore, among others (Paradise, 2010).

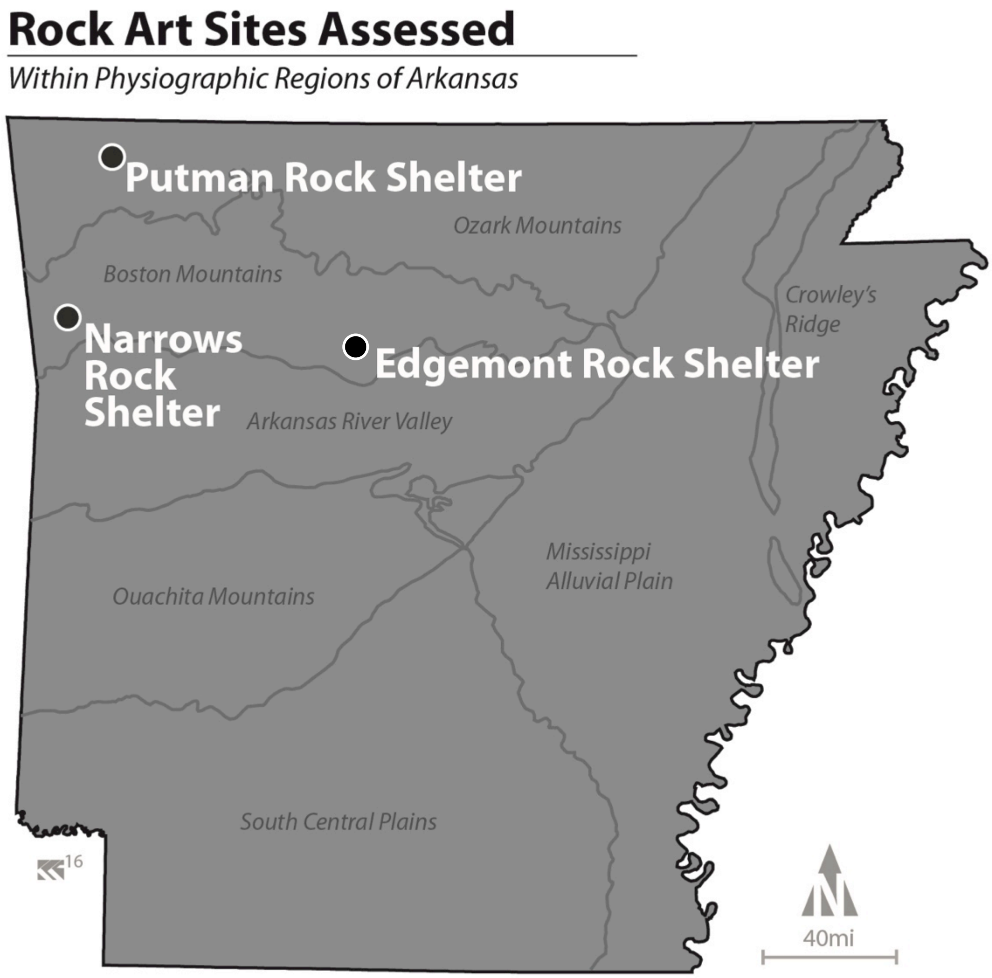


Figure 4.1: General locations of the three assessed rock art sites and the general physiographic regions of Arkansas. Cartography by author, 2016, based on Paradise (2010).

Arkansas's numerous natural resources and scenic landscapes drive the state's booming tourism industry, with over 28 million tourists spending nearly $7.2 billion in 2015 (ADoPT, 2016), but these very same features might have also attracted prehistoric peoples to the region thousands of years ago. The first known inhabitants of the mid-South region were Paleo-Indians, thought to have migrated to the Mississippi Valley from the Great Plains roughly 12,000 year ago, first occupying the southern delta region before expanding into the Arkansan Ozark and Ouachita Mountains and Gulf Coastal Plain at the end of the Ice Age (Sabo III, 2005c). Since then, Arkansas was home to several eras of Native American civilization. The most notable of these include the Archaic Era (9500 – 650 BC), when native peoples

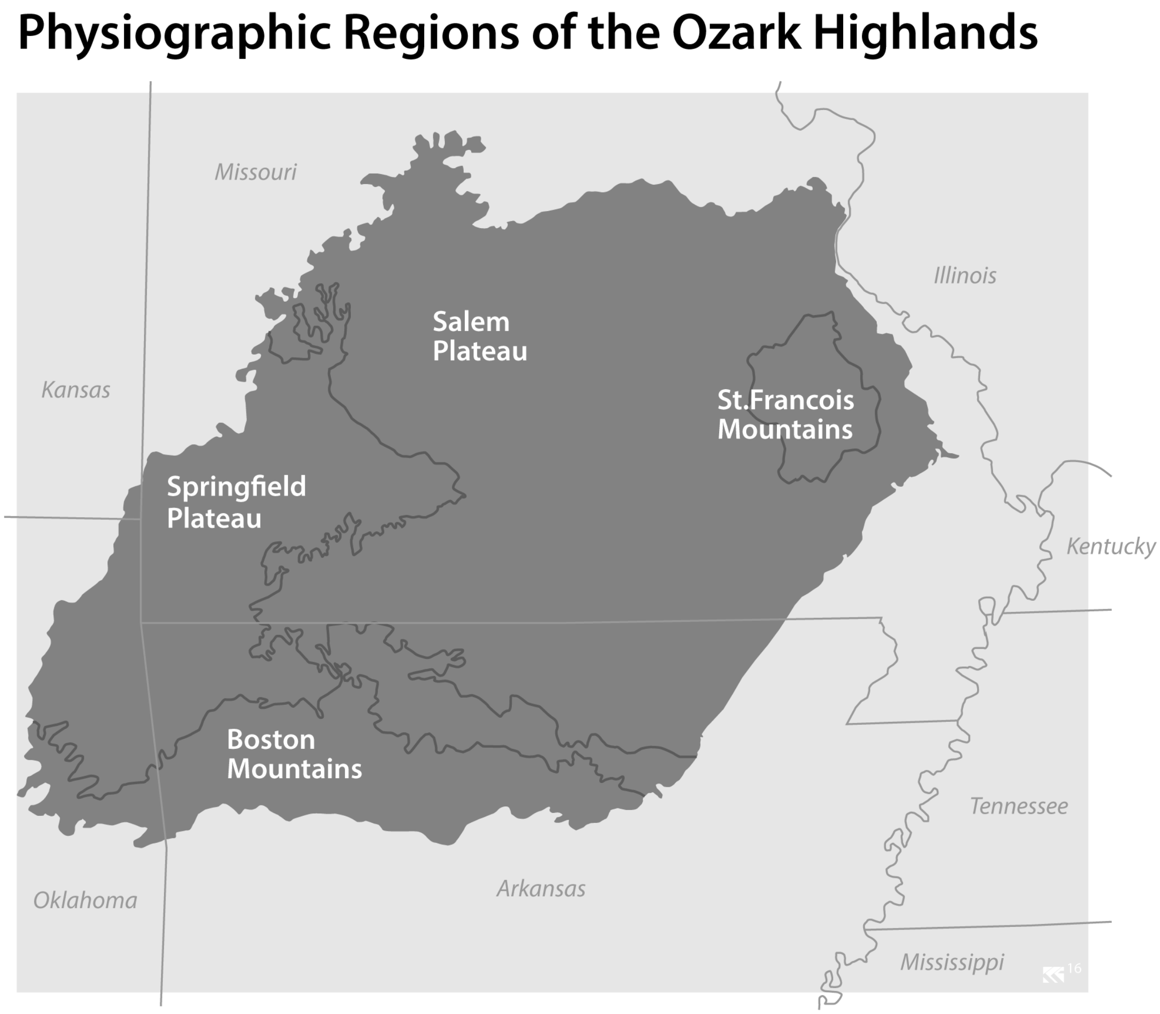


Figure 4.2: The extent and characteristics of the physiographic regions of the Ozarks, ranging from northern Oklahoma and Arkansas to the southeast corner of Kansas and a large swath in southern and central Missouri. Cartography by author, 2016.

adapted to the changing climate and initiated plant domestication and agriculture; the Woodland Period (600 BC – AD 1000), which witnessed the development of social structures and trade economies as well as technological advancements such as fired clay pottery and bows and arrows; and the Mississippi Era (AD 900 – AD 1600), when the largest and most complex communities developed, such as the Caddo (Paradise, 2010). Rock art motifs and styles have been used to tentatively date some of Arkansas's petroglyphs and pictographs to each of these eras, but most are thought to belong to the most recent Mississippi Era (Sabo III, 2005c). Scientific dating analyses using more rigorous methods, such as radiocarbon dating, has only been conducted at a handful of sites in Arkansas (e.g. Hilliard, 2010), leaving any reliable chronology for Arkansan rock art yet to be developed. More detailed dating estimates for each rock art site in this study will be addressed as part of the final discussion following results and analysis.

Following European contact by Spanish explorer Hernando de Soto (1539 – 1543), Arkansas's cultural landscapes underwent several significant periods of change, for both native occupants and new arrivals. Initial expeditions and subsequent colonization in the Ozarks were marked with the spread of diseases and conflict with local peoples, exacerbated by intense droughts throughout the region (Sabo III, 2005c). These trials are reflected in contemporary rock art depictions of battle with firearms and horses, not native the to area, as well as European Latin inscriptions possibly created in this early Euro-American period. Later included in the 1803 Louisiana Purchase, Arkansas became part of the United States of America and within a few decades five distinctive Native American Tribes were forcibly relocated to reservations in what is now Oklahoma, with Arkansas as a primary route (Paradise, 2010). Historic trails now mark the "Trail of Tears" along which the Chickasaw, Choctaw, Creek, Cherokee, and Seminole tribes made their way through Arkansas to Oklahoma, many of which not surviving the strenuous journey (Sturgis, 2007). The state was later torn during the American Civil War (1861-1865), with many people in northwest Arkansas supported the Union despite the state's official Confederate allegiance (Paradise, 2010). Some of the largest battles west of the Mississippi took place in Arkansan territory (Shea & Hess, 2011). More recent history of Arkansas is marked with great floods in the early 1900s, civil rights movements during the 1950s-60s, and continued development to this day, all of which have potential impacts on the survival of the state's ancient rock art. Whether it's historic bullet damage from the Civil War to derogatory vandalism to simple construction and expansion, the rock art in Arkansas have endured countless threats and require further scientific examinations in order to ensure their continued conservation into the future.

4.1.2 – Existing Rock Art Research in Arkansas

Despite the state's rich archaeological and heritage resources, very little research has been conducted on Arkansan rock art—even in the early years of American archaeology. Many of the historic publications that do exist often exhibit the casual tone, cultural stereotypes, and speculations common in early-mid century archaeological reports (Sabo III & Hilliard, 2005). For example, the first scholar to officially record Arkansan rock art, Green (1883) described the petroglyphs as “Curious characters… cut into the rock… by some blunt instrument in the hands of an unskilled sculptor” (p. 539, as quoted by Sabo III & Hilliard, 2005). He goes on to speculate how architectural features of rock art sites in Johnson County, Arkansas, would resonate with “superstitious aborigines” and how they could be useful “in time of war” (Green, 1883, p. 538)—reflecting a preconceived “war-like” assumption regarding Native Americans in the late-nineteenth century. Through the decades that followed, only a handful of other scholars researched the plentiful rock art across Arkansas. Such scholars include Walker (1932), who was the first to acknowledge the relationship between rock art with adjacent archaeological remains in Arkansan rock/bluff shelters, and Hardison (1955), who, along with R.H. Torrey and C. Wissler, pioneered rock art research at what is now Petit Jean State Park in central Arkansas (Higgins Jr, 2014).

Beyond the prejudiced observations and superfluous commentary, early descriptions of Arkansan rock art provide valuable conditional baselines for modern assessments—many of which have been conducted through the Arkansas Archaeological Survey in partnership with the University of Arkansas. Among the first contemporary rock art studies in the state was a systematic revisit and cataloging of Arkansan rock art mentioned in old reports, revealing a concentration in the southern Ozarks and Arkansas River Valley (Fritz & Ray, 1982). Fritz and Ray were also pivotal in the nomination, and subsequent induction, of 28 rock art sites in the National Registrar of Historic Places—marking the nation’s first ever thematic nomination for rock art (Sabo III & Hilliard, 2005). Further efforts to accurately record Arkansan rock art have included more in-depth surveys of the Narrows and Putnam rock shelters (Hilliard, 2004, 2010), along with past and ongoing projects run through the Arkansas Archaeological Survey, such as the “Arkansas Rock Art Project” funded by the Arkansas Humanities Council and the National Endowment for the Humanities designed to expand research specifically focused on Arkansan rock art (Sabo III & Hilliard, 2005).

While the Arkansas Archaeological survey has continued to produce significant research regarding Arkansan rock art, most publications have focused on humanistic or historical elements of the art, such as discovering meaningful distributional patterns in motifs and design content (Sabo III et al.,

2015) or devising digital landscapes as a means of protecting fragile sites (Sabo III & Shortridge, 2005), but a disproportionately few studies have addressed the physical condition of the sites and stones themselves. Representing the first modern study addressing rock art geologic stability in Arkansas, geography student Kupillas (2014) attempted to determine environmental influences on the deterioration of rock art at the Narrows Rock Shelter, thus incorporating rock decay assessments for the first time at this site—and in the state. However, considerably more research is necessary if the myriad of Arkansan rock art is to be conserved into the future—research such as that presented here and in the previously published work upon which this case study is heavily based (i.e. Groom, 2016a; Groom, 2016b). While this chapter concentrates more on the applicability of pairing two different rapid field assessment techniques, the regional context and significances of the work is also highlighted at each site.

It is also important to note the different techniques used to create rock art, as these influence how the images decay. For the Arkansan Ozarks, rock art techniques vary significantly (Sabo III, 2005b)—exemplified by the assortment of techniques employed at the three study sites. The Narrows Rock Shelter contains mostly petroglyphs (created through the removal of material at the stone's surface via pecking or incising), although some displayed minute evidence of pigment within specific carved motifs. The Edgemont Rock Shelter also houses petroglyphs, although, unfortunately, many have been partially or entirely covered by lichen and/or moss. Alternately, the rock art at the Putnam Rock Shelter are exclusively pictographs (made by adding materials—such as paints, chalk, or charcoal—to the stone surface). At Putnam, the images are composed of predominantly red and black pigments, though there are a few instances where white might also have been used. Understanding basic rock art techniques and materials used is vital to identifying how they decay and detecting which natural and/or anthropogenic processes represent the greatest threat to their continued survival.

4.2 – CASE-SPECIFIC METHODS

This case study examines the applicability and suitability of pairing two rapid field assessment techniques in attempt to create a more holistic rock art decay research approach without threatening the stability of the host stone. In order to incorporate both quantitative and qualitative methods, this study used the Rock Art Stability Index (RASI) and Repeat Photography, respectively. As outlined in the preceding chapter, both methods have their own series of strengths and weaknesses. The intention of this case study is to see if employing more than one complementary RFA technique will help counter the limitations of the individual techniques. Since thorough explanations of both technique characteristics and procedures were provided in Chapter 3, method details for this case study will be limited to the source material for the historic repeat photography. For clarification or other technique-related questions, consult the previous chapter.

Historic photographs for the three sites were part of a 1930s collection housed in the University of Arkansas Museum partnered with the Arkansas Archeological Survey. Despite limited attention from the academic research community, the museum and survey have continued to promote archaeological exploration and protection of the state's historic and pre-historic heritage. Curator of the University of Arkansas Museum in the early-mid 1900s, Samuel C. Dellinger (1892 – 1973), affectionately referred to as "Raider of the Lost Arkansas" (Mainfort, 2008), was particularly passionate about Arkansas's Native American heritage. On many occasions he openly objected the volume of excavated archeological material exported and exhibited in non-Arkansas museums (Lankford, 2009). To counter what he saw as a depletion of local heritage, Dellinger procured numerous research grants to fund locally sourced archeological field crews to survey across the state throughout the 1930s, compiling a nationally praised archeological museum collection in the process (Mainfort, 2008). Included in many of these surveys were detailed photographic records depicting the excavated sites—including both the Putnam and Edgemont Rock Shelters. While one of Dellinger's teams also excavated the Narrows Shelter, historic photographs were not taken, therefore, the photos repeated at this site date to the 1950s. This temporal discrepancy is acknowledged in the individual analysis of the site and in cross-site comparisons later in the discussion and conclusions.

Preceding results and analysis, it is prudent to point out that the most striking difference between the historic photographs and their modern repeats (at all three sites) is the presence of what is known in the rock art community as chalking—artificially coloring or tracing the art to make the motifs more visible. The controversial practice was commonplace during the early to mid-20th century, but now chalking is widely regarded as harmful to the rock surface and its use is strongly discouraged in the United States (Bock, 1981; Francis et al., 1993; Leen, 1981). However, it is still concidered a form of conservation in other parts of the world, such as the Scandinavian Tanun Rock Art Research Centre that routinely paints petroglyphs white to maintain motif clarity (Jones, 2016). In the Arkansan Ozarks, each of the historic photographs exhibit chalking while the modern repeats do not, making some features more difficult to distinguish in the contemporary photographs.

4.3 – RESULTS AND ANALYSIS

While the diversity of the three sites in this case study provides a more representative collection of Arkansas's rock art resources, it also reveals unique challenges and decay processes affecting each site differently. As such, the results from each site were analyzed individually and then compared. Some of the fundamental differences among the sites, such as rock art age and lithologies, discourage direct comparisons but general patterns regarding "Arkansan rock art" are speculated in a following sub-chapter.

4.3.1 – The Narrows Rock Shelter

Home to some of the most recognizable petroglyphs in the Arkansan Ozarks, the Narrows Rock Shelter is a relatively small cave/rock shelter owned by the U.S. Forest Service in Crawford County. Found mere meters from the road, the site, known locally as the Indian Writing Rocks, encompasses several petroglyphs and various archeological materials estimated to date around 1425 AD (Hilliard, 2010), most of which is now housed in University of Arkansas Museum. Bordering the Boston Mountain system and the Arkansas River Valley, the rock shelter is mainly composed of the Atoka sandstone formation, a fairly resilient capstone positioned above numerous siltstones and shales in the region (Adamski et al., 1995). Positioned against a moderately steep slope, debris and rainwater runoff often infiltrate the rock shelter, depositing materials that have slowly inundated much of the site. Rain and spring water also drip off the shelter ceiling and overhang, potentially exacerbating superficial rock decay processes, such as abrasion and flaking. Additionally, the opening of the rock shelter is in close proximity of thick vegetation—mainly shrubs and deciduous trees—that could cause stability issues if they grew too close to the shelter walls.

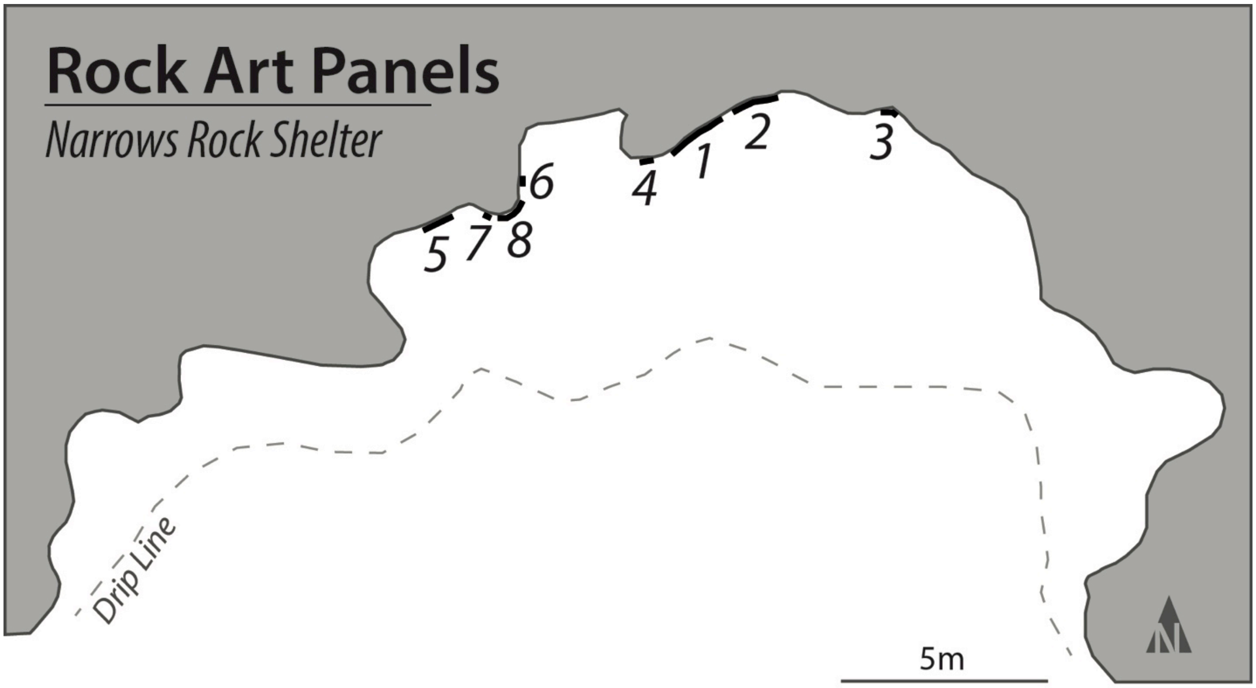


Figure 4.3: Map showing the rock art panel locations within the Narrows Rock Shelter. Map by author with the permission from the Arkansas Archeological Survey, 2014.

General awareness of its existence and easy access to the site, thanks to a stone staircase built by the Civilian Conservation Corps in the 1930s (Hilliard, 2010), has encouraged numerous visitations to the shelter. While many of these include educational endeavors, such as school field trips and local politicians getting involved in conservations efforts, visits to the site are not always positive. Evidence of frequent criminal behavior, including looting, vandalism, and illicit substance abuse, represent significant challenges for the long-term heritage management at the site (Hilliard, 2010). However, the infamy of the Narrows' conservation obstacles have attracted academic attention as well, inspiring some of the state's first non-archeological scientific research of Arkansan rock art (e.g. Groom, 2016a; Hilliard, 2010; Kupillas, 2014). This case study could be considered a continuation of this work. In total, nine rock art panels were assessed with RASI (Figure 4.3) and while many were attempted, only two photographs were successfully repeated.

RASI

Average 36.25 in RASI, the petroglyphs at the Narrows Rock Shelter are classified as having *Problem(s) that Could Cause Erosion*, one of the more moderate categories. Panel scores varied somewhat with the lowest score being 31 (Panel six: *Problem(s) the Could Cause Erosion*) and highest of 42 (Panel one: *Urgent Possibility of Erosion*); only three panels scores above 40 (Table 4.1). The site's scores displayed a few structural concerns, particularly in terms of fissures, both dependent and independent, and imminent undercutting. However, the most significant issues seem more topical in nature. Incremental lose due to granular disintegration, flaking, lithobiont activity, and textural anomalies prompting differential decay all scored high on most, if not all, panels. These superficial decay processes also initiated the developments of secondary decay issues, such as loss of rock coatings and rounding of petroglyph edges. Also a major concern, the setting and topography of the surrounding hillside have led to significant sedimentation within the rock shelter, in some places nearly to the petroglyphs themselves, assumed to have been created at or near eye level. Sedimentation can be a complicated management topic. Some scholars purposefully bury rock art as a means of conservation and protection (Ernfridsson et al., 2010) while in other circumstances structures or retaining walls have been built to prevent rock art burial (Allen & Groom, 2013a). At the Narrows, the issue is even more complicated as ample looting and unauthorized digging have radically altered the floor topography within the shelter and threaten the stability of its numerous petroglyphs.

However, despite these concerns and the site's notoriety, the RASI scores are still relatively moderate, much lower than expected for such a heavily impacted site. This could be due to a general lack of rock decay processes typically found in sandstone. Common sandstone decay forms found throughout much of the US Southwest, such as splintering, salt development, or fissuresol detachment, are largely absent at the Narrows. Splintering and salt development often reflect inherent stone weaknesses so their absence may indicate the substructure is relatively stable regardless of topical or superficial concerns. Additionally, while there is an abundance of anthropogenic carving (e.g. initials or dates) throughout the shelter, most panels are at or near floor level due to heavy sedimentation and difficult to reach so there is very little vandalism near the petroglyphs themselves—effectively decreasing their significance on final RASI scores. That said, the widespread modern inscriptions still impact the aesthetics of the site and continue to be a management problem despite their relative separation from the eight main rock art panels, exemplifying one area where RASI lacks the ability to address the total landscape as a whole. Repeat photography supplementation can help fill this assessment gap.

Narrows Rock Shelter RASI Report			
Panel Number	RASI Score	Category	Major Issues
1	42	Urgent Possibility of Erosion	*Lithobiont Pitting, Flaking, Moss*
2	34	Problem(s) that Could Cause Erosion	*Textural Anomalies, Moss, Rock Coating Detachment, Vandalism*
3	40	Urgent Possibility of Erosion	*Weathering Rind Development, Granular Disintegration, Vandalism*
4	35	Problem(s) that Could Cause Erosion	*Wicking, Granular Disintegreation, Lithobiont Pitting*
5	34	Problem(s) that Could Cause Erosion	*Independent Fissures, Undercutting, Rounding of Petroglyph Edges*
6	31	Problem(s) that Could Cause Erosion	*Water Flow, Rock Coating Detachment, Rounding of Petroglyph Edges*
7	33	Problem(s) that Could Cause Erosion	*Dependent Fissures, Splintering, Undercutting*
8	41	Urgent Possibility of Erosion	*Dependent Fissures, Granular Disintegration, Lithobiont Release*
Avg:	36.25		

Table 4.1: RASI scores for each panel at the Narrow Rock Shelter and primary concerns impacting that panel.

Repeat Photography

Where the RASI assessment focused on quantifying structural stability, repeat photography was used to provide qualitative context for those values and to appraise the visual status of the Narrows petroglyphs—essentially gage how the aesthetics of the site may have changed over the last six decades. Multiple photographs were attempted but due to accessibility challenges, poor lighting, and low image quality of the historic pictures, only two were repeated successfully: Panels 1 and 7. Fortunately, these are two of the most recognizable panels from the Narrows and are often displayed in publicity material for public and/or academic purposes (e.g. Arkansas Archaeological Survey newsletters/website decoration). This use presents precedence for using panels 1 and 7 as representative panels for the Narrows, as well as Arkansan rock art in general.

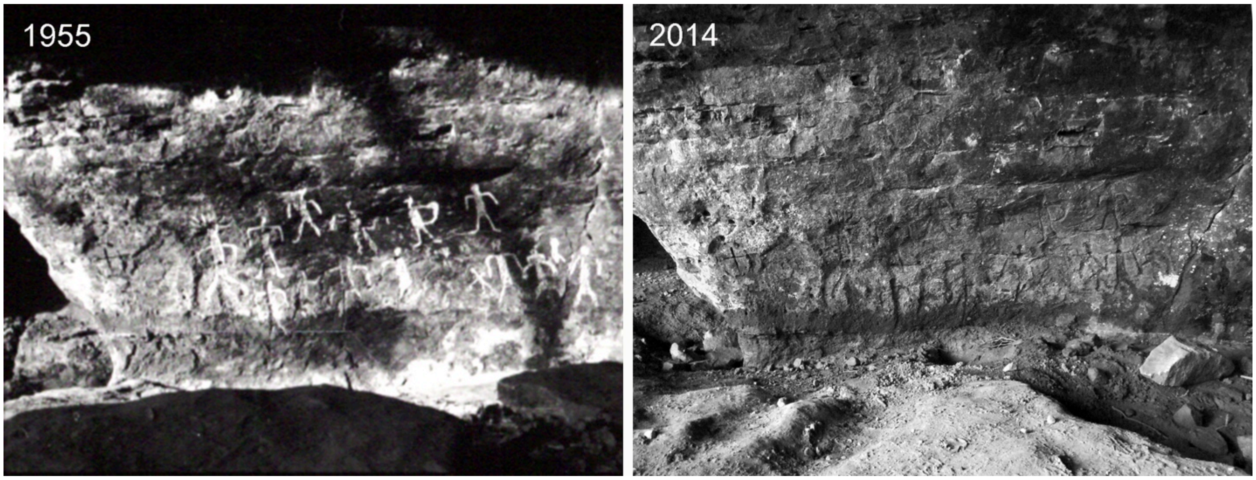


Figure 4.4: Left: 1955 photograph of Panel 1 at Narrows Rock Shelter from the University of Arkansas Museum with permission of the Arkansas Archeological Survey. Right: 2014 repeat photograph by author.

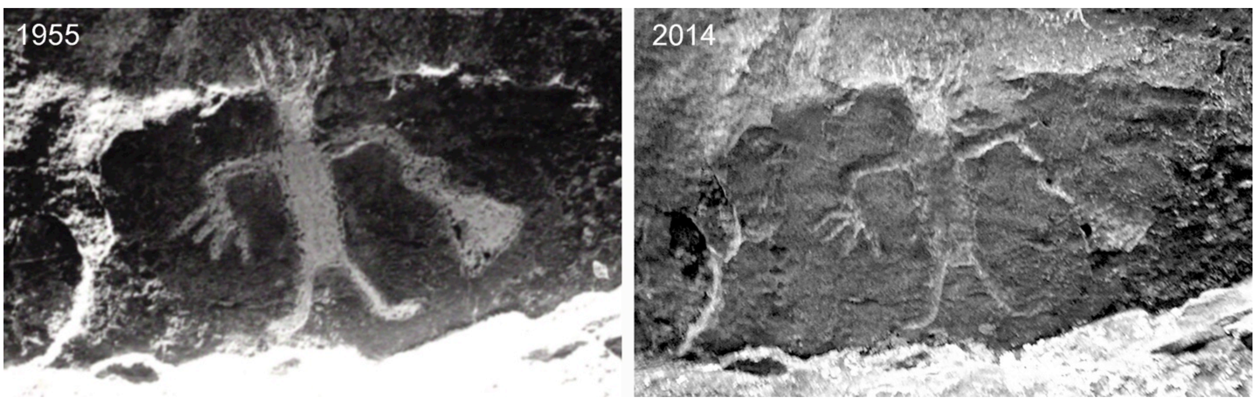


Figure 4.5: Left: 1955 photograph of Panel 7 at Narrows Rock Shelter from the University of Arkansas Museum with permission of the Arkansas Archeological Survey. Right: 2014 repeat photograph by author.

The first panel repeat photographed, panel 1, is one of the largest and most intricate panels at the Narrows displaying multiple anthropomorphs, one of the largest wearing a head-dress (mid-left), and a geometric encircled cross near the far left of the panel (Figure 4.4). Aside from the white chalking in the historic image, there appear to be relatively few noticeable changes between the photographs. One of the most significant differences is contextual: the ground around the base of the panel displays considerable disturbances, possibly the result of looting and illegal extraction of any remaining archaeological material. This speculation is supported by the presence of a substantial looting pit along with evidence of illicit substance abuse a few feet beyond the frame of the repeated photograph. Most specific to the petroglyphs themselves, flaking and textural changes appear to have worsened, making the individual motifs difficult to identify. However, somewhat contradictory, several of the petroglyphs, particularly near those on the right indicate some degree of what looks like repatination—re-accumulation of rock coatings within the removed surface of a petroglyph (Dorn, 1998)—though a more detailed analysis would be necessary to confirm this.

Providing a much intimate assessment of the petroglyphs at the Narrows, the second photograph repeated is a close up of panel 7, exhibiting a lone anthropomorph wielding a mace-like or fan-like object (Figure 4.5). The clarity and depth of the glyph, despite poor image quality for both historic and modern photographs, reveal a number of changing issues and provides some insight into the unexpectedly low RASI scores. For example, the textural anomalies and flaking that dominated the RASI assessments show to have advanced over the decades, particularly to the right of the glyph, where the surface appears significantly rougher and flaking has begun degrading the lower left corner of the mace/fan. That said, many parts of the panel, especially the head, body, free hand, and the surface immediately surrounding the motif, shows surprisingly little change. Similar to sections of panel 1, much of panel 7 displays evidence of repatination—general darkening within the petroglyph relative to the unworked stone surface—creating a more uniform coloration across the entire panel.

The presence of repatination, a process requiring moderately stable conditions over a substantial period of time (Dorn, 1998), provides some explanation for the unexpectedly low RASI scores—especially since the historic photos for this particular site were only taken in the 1950s. The surface within the petroglyphs must have been relatively stable for some time to allow to repatination to occur and, in turn, the newly accumulated rock coating serves to stabilize the rock art further, diminishing the influence of several sandstone decay processes—a trend revealed in the site's RASI scores. This is not to say rock decay cannot occur on repatinated surfaces, it simply provides added protection in the future and indicates, at least to a certain degree, that the panel has had long periods of stability in the past—important contextual information ascertained by jointly employing RASI and repeat photography complementarily.

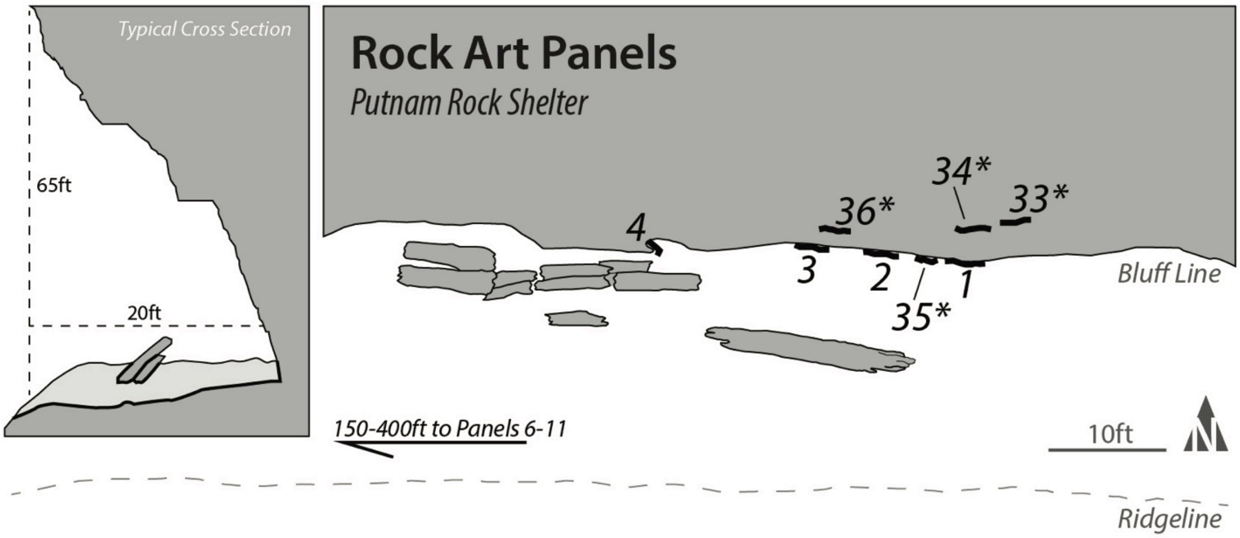


Figure 4.6: Map of primary rock art wall at Putnam Rock Shelter with generalized cross-section to show the shape of the bluff shelter. Several previously recorded panels at this site were not located but new panels were also discovered (marked with an asterisk). Cartography by author, 2014, with permission of the Arkansas Archaeological Survey.

4.3.2 – Putnam Rock Shelter

The only site north of the Boston Mountains, the Putnam Rock Shelter is located at the base of a cliff on the Springfield Plateau, one of the primary highland components of the Ozark Plateau. With its inclusion in the Springfield Plateau, the site sits squarely in the Boone Limestone Formation—a relatively less resilient lithology than the Atoka Sandstone found at the Narrows. The Putnam rock art, consisting of black and red pictographs, have been contextually dated to around 1550-1600 AD, although there is some speculation on whether their creation was even more recent (Hilliard, 2004). Once completely beyond reach, the environmental and situational context of the site changed dramatically with the creation of Beaver Lake, a large state reservoir built in 1966. Bordering private and U.S. Corps of Engineers property, the site now sits atop a steep talus slope leading directly to the water's edge, making the site reachable by boat—although the steep incline and loose material still leave the site particularly challenging to access.

The now-close proximity to Beaver Lake has made water a major challenge for the conservation of this site—especially since the rock art here is exclusively pictographs and prone to fading. The cliff is presently five meters above the lake's normal surface elevation, however, U.S. Corps of Engineers records reveal at least three flood events (2008, 2009, and 2011) with the intensity necessary to inundate site for extended periods (i.e. over two weeks)(Evans, 2013). Such flood events risk detaching paints and other pictograph material from the cliff walls, as well as introducing new minerals or flood debris to the surrounding landscape or rock surfaces with may negatively impact site stability (Allen & Groom, 2013a). In addition, in the 1980s, the Corps planted several pine trees to hide many of the pictographs—obscuring the site from the lake to discourage curious visitors.

The remoteness and accessibility difficulty has both benefited and hindered conservation efforts at the Putnam shelter: any evidence of vandalism or looting is practically nonexistent, but, at the same time, academic and scientific research at this site is also relatively limited. The site was first surveyed and photographed through Dellinger's archeological program in 1932, when the bluff was also roughly excavated (Cleland, 1965)—large troughs and excavation pits still mark much of the landscape at the base of the long cliff. Later in 1978, State archeologist Gayle Fritz reassessed the shelter to verify if the site's fragile rock art was still intact (Hilliard, 2004). One of the more dramatic repeat photography pairing involves a photograph taken during this visit (See Figure 4.7). Since then, the only other archeological examination of the site was in 1986 as part of the "Dellinger Revisited" project run through the Archeological Survey (Hilliard, 2004). That said, most of these studies were primarily dedicated to excavation of buried archaeological material and very few involved rock art beyond simply acknowledging their presence or taking pictures (Cleland, 1965; Hilliard, 2004). This case study represents the first geologic stability analysis specifically focused on the Putnam Rock Shelter pictographs—in total 13 panels were assessed with RASI, including a large buffalo motif on an adjoining cliff, and three photographs were successful. Since previous epigraphic and rock art investigations at this site were minimal, many of the panels evaluated had never been officially recorded and thus given new designations, such as UR-E ## (***U***n-***R***ecorded ***E***lement), and the length of the bluff presented cartographic challenges so the primary site/panel map concentrates on the main bluff area with the highest concentration of rock art panels, including the panels depicted in the repeated photographs (Figure 4.6).

RASI

With an overall RASI site average of 41.15, the Putnam pictographs are classified as *Urgent Possibility of Erosion*, the third highest category. Only three panels earned scores low enough to classify as having *Problem(s) That Could Cause Erosion*, and the lowest of these (panel AS-1: 33) was actually on an adjacent bluff not assessed during Dellinger's original 1932 survey but often associated with Putnam and rock art surrounding Beaver Lake. The lowest scoring panel at Putnam proper (panel UR 34: 34) was a previously unrecorded motif above the surveyed panel one. Many of Putnam's highest scoring panels, such as panel two (49: *Urgent Possibility of Erosion*), near the qualitative threshold of the second highest stability category: *Great Danger of Erosion* (Table 4.2).

Putnam Rock Shelter RASI Report			
Panel Number	RASI Score	Category	Major Issues
AS 1	33	Problem(s) that Could Cause Erosion	*Flaking, Scaling, Splintering, Undercutting*
1	43	Urgent Possibility of Erosion	*Dependent Fissures, Scaling, Flaking, Weathering Rind, Undercutting*
UR-E 35	43	Urgent Possibility of Erosion	*Scaling, Flaking, Undercutting, Weathering Rind, Splintering*
UR-E 33	42	Urgent Possibility of Erosion	*Dependent Fissures, Scaling, Flaking, Weathering Rind, Undercutting*
UR-E 34	34	Problem(s) that Could Cause Erosion	*Scaling, Flaking, Weathering Rind, Splintering*
2	49	Urgent Possibility of Erosion	*Dependent Fissures, Scaling, Flaking, Undercutting, Splintering*
UR-E 36	44	Urgent Possibility of Erosion	*Dependent Fissures, Scaling, Flaking, Weathering Rind, Splintering*
3	42	Urgent Possibility of Erosion	*Scaling, Flaking, Splintering, Undercutting, Weathering Rind*
4	38	Problem(s) that Could Cause Erosion	*Dependent Fissures, Undercutting, Scaling, Rock Coating Detachment*
6	40	Urgent Possibility of Erosion	*Dependent Fissures, Scaling, Splintering, Undercutting*
8	42	Urgent Possibility of Erosion	*Splintering, Weathering Rind, Rock Coating Detachment, Scaling*
10	45	Urgent Possibility of Erosion	*Dependent Fissures, Textural Anomalies, Plant Growth, Flaking*
11	40	Urgent Possibility of Erosion	*Splintering, Scaling, Rock Coating Detachment, Blurring of Edges*
Avg:	41.15		

Table 4.2: *RASI scores for each panel at the Putnam Rock Shelter and primary concerns impacting that panel.*

Unlike the superficial concerns of the Narrows Rock Shelter, many of the Putnam Rock Shelter's primary problems seem to be more structural. Among the consistently high-scoring decay processes identified by RASI are dependent fissures (jointing parallel to the lithological bedding plane), generally low rock hardness, undercutting, and splintering—each indicating a certain degree of internal instability. Exemplifying the seriousness of such weaknesses, at least one pictograph has been completely halved since the 1970s due to intense undercutting (Figure 4.7). Additionally, many panels display evidence of developing weathering rinds—a thin coating that accumulates as internal rock minerals migrate to the surface, often leaving the underlying depleted of the protective minerals and more susceptible to enhanced deterioration (Oguchi, 2004).

While most of the more pressing issues are structural, the site's RASI scores also identified a number of surface decay processes threatening motif clarity and panel stability. For example, most panels steadily scored high on flaking and scaling, both impending and occurred, identifying these processes as potential risks of further deterioration in the future—especially as much of the flaking has already started directly impacting the painted motifs (Figure 4.8). Many panels also exhibited intense fading of both pictograph paints and protective rock coatings, likely the result of repeated flooding and water damage, obscuring several of the motifs and making them quite difficult to identify. So much so, that the members of the 2014 field research team were unable to find a number of panels listed in the original site records. Vegetation, both on and near the bluff walls, also presents visibility and surface deterioration concerns. Multiple trees planted by the Corps have become problematic. They may have served their purpose of blocking views of the rock art from offshore, but they have also grown too close to the panels—increasing the risk of abrasion and fire damage. Even more invasive, several vines have overgrown large areas of the bluff wall, possibly abrading or concealing pictographs as well as introducing further structural stresses by means of root wedging.

Regardless of the outlined structural and topical concerns at the Putnam Rock Shelter, the RASI scores themselves only address the stone surfaces immediately surrounding pictographs and, as such, they may misrepresent the stability of the site as a whole. For example, many panels containing rock art, in and of themselves, actually appear relatively stable, thus earning lower RASI scores, but when the bluff shelter is analyzed as a whole these "stable" panels occupy a comparatively weak and vulnerable

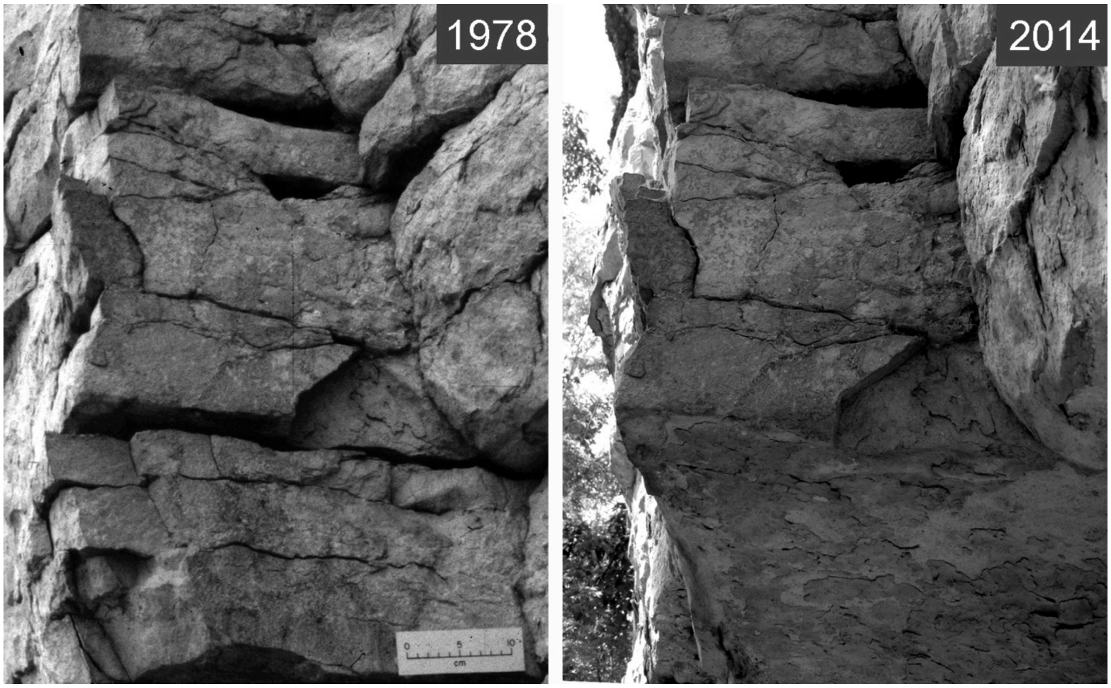


Figure 4.7: 1978 (left, shown with permission of the Arkansas Archeological Survey) and 2014 (right, by author) photographs showing significant loss due to undercutting.

Figure 4.8: Close up view of intense weathering rind development and flaking of a singe red circular pictograph at the Putnam Rock Shelter. Photograph by author.

substrate. Perhaps then, the severity of cultural stone decay risk present at the Putnam Rock Shelter is alarmingly understated by RASI analysis alone—necessitating the contextual supplementation and visualization of overall decay proved through historic repeat photography.

Repeat Photography

Despite the size and sprawl of the Putnam Rock Shelter only two historic Dellinger photographs were successfully repeated. There were several others but the intense fading and deterioration of the pictographs, as well as little archival information of the recorded panels' locations, rendered most images unsuitable for reliable repeat photography. Exemplifying this difficulty, both successful repeated panels were identified by matching unique geomorphologic features on the cliff face, not the art itself, as the motifs were extremely faint and difficult to find on their own. As a side note, with pictographs instead of petroglyphs, historic chalking visible in the Dellinger photos merely circles groupings of motifs, not tracing individual elements as is common with petroglyphs.

Exhibiting one of the most intact pictographs at the site, the first repeated photograph features panel 4—a large red concentric circle on a protruding ledge (Figure 4.9). Evidence of rock fall and/or undercutting along the outer cliff face is visible to the left of the motif, particularly around the lower ledges. Even more significant, however, is the dramatic change in potentially beneficial rock coatings covering the panel itself. The historic image displays a relatively healthy coating of dark varnish across most of the

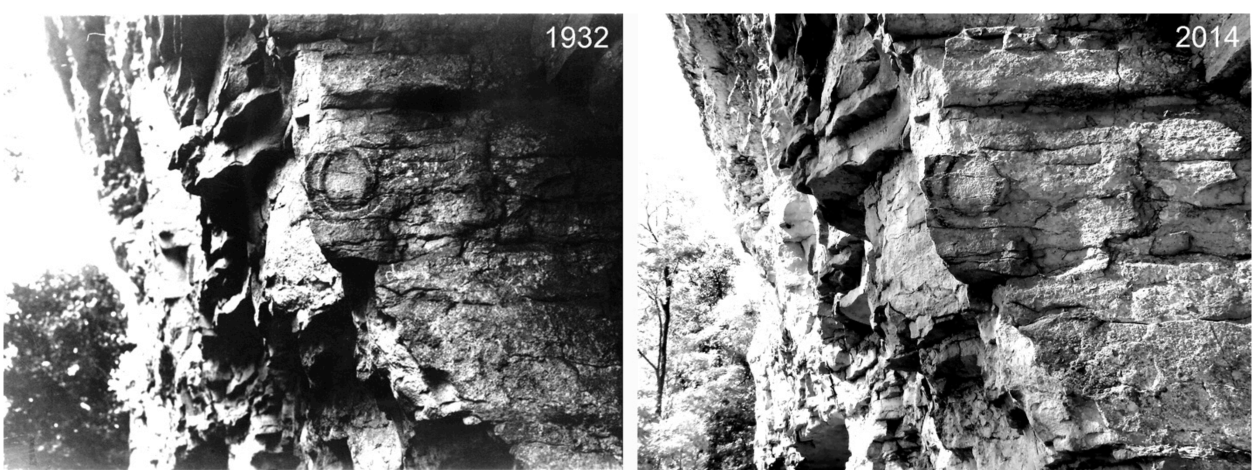


Figure 4.9: Left: 1932 photograph of Panel 4 at Putnam Rock Shelter with permission of the Arkansas Archeological Survey. Right: Repeat photograph by author, 2014.

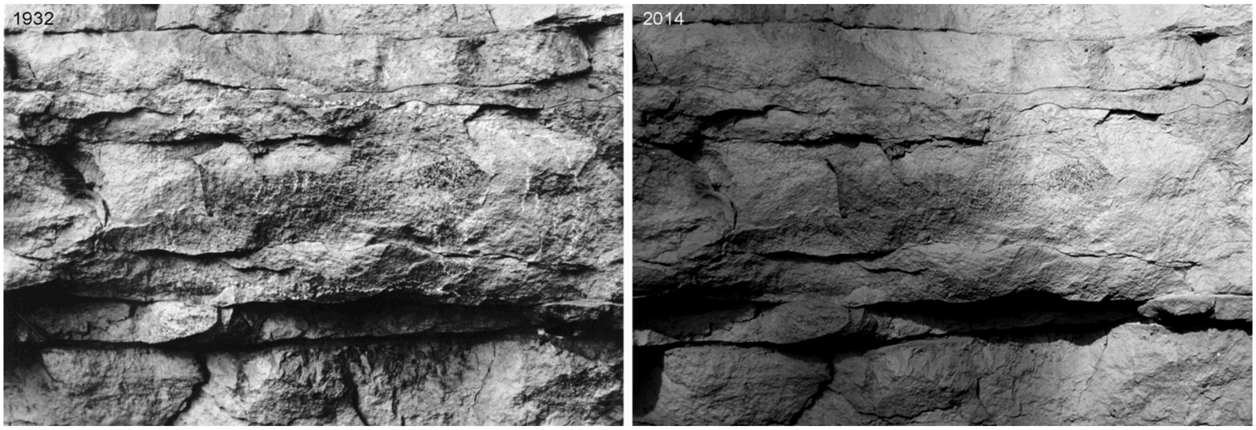


Figure 4.10: Left: 1932 photograph of Panel 8 at Putnam Rock Shelter with permission of the Arkansas Archeological Survey. Right: Repeat photograph by author, 2014.

panel, while the panel in the modern photograph reveals rampant flaking and a significantly lighter and less stable surface. This pattern could possibly be explained by considerable changes in lithobiont and lichen activity. Lichen and mosses appearing to cover much of the panel's lower and interior surfaces are easily visible in the historic image but are practically absent in the modern repeat. Flaking paired with the destabilizing effects of lithobiont digestion of rock coatings and ultimate detachment may have attributed to the depletion of the protective rock coatings seen in the historic image.

Remarkably less intact, the pictograph featured in the second repeat photograph is the faded remnants of a speculated red quadruped on panel 8, though not enough remains to be definitive (Figure 4.10). The painted feature is incredibly worn, even in the historic 1930s photograph, where it is shown circled with white chalk. However, besides the pictograph's faintness, there are very minimal geomorphologic or decay differences between the photographs, which is somewhat contradictory to the panel's relatively higher RASI score for the site (42 – *Urgent Possibility of Erosion*). There are two possible explanations for this apparent discrepancy. The first is a contradiction of geologic and human timeframes: the panel could have experienced its substantial decay beyond the geologically insignificant time period between the two photographs. The second possibility entails the RASI analysis inadvertently integrating elements of inherited decay—rock decay preceding rock art application (R.I. Dorn, 2006)—in the final assessment of rock art stability. In either case, the repeat photography provided additional temporal and contextual information on decay patterns otherwise absent with a RASI analysis alone.

4.3.3 – Edgemont Rock Shelter

Neighboring the Little Red River Valley in the Boston Mountains and composed of the fine-grained Morrowan Witts Springs sandstone formation (Hutto & Rains, 2014), the Edgemont Rock Shelter (also called the Indian Rock House) is unique among the three study sites. Demonstrating the complicated relationship between cultural resource management and popular use of heritage, Edgemont is privately owned by the Wyndom Indian Hills Resort at Fairfield Bay and frequently displayed in resort advertisements and promotions. Pictures of both the cave and its many petroglyphs are publicized on roadside billboards, the shelter's opening is immediately adjacent to the golf course, and the relatively larger interior space has hosted concerts, picnics, and other public community events. In fact, a performance stage has been built directly into the back wall of the shelter near a small natural spring.

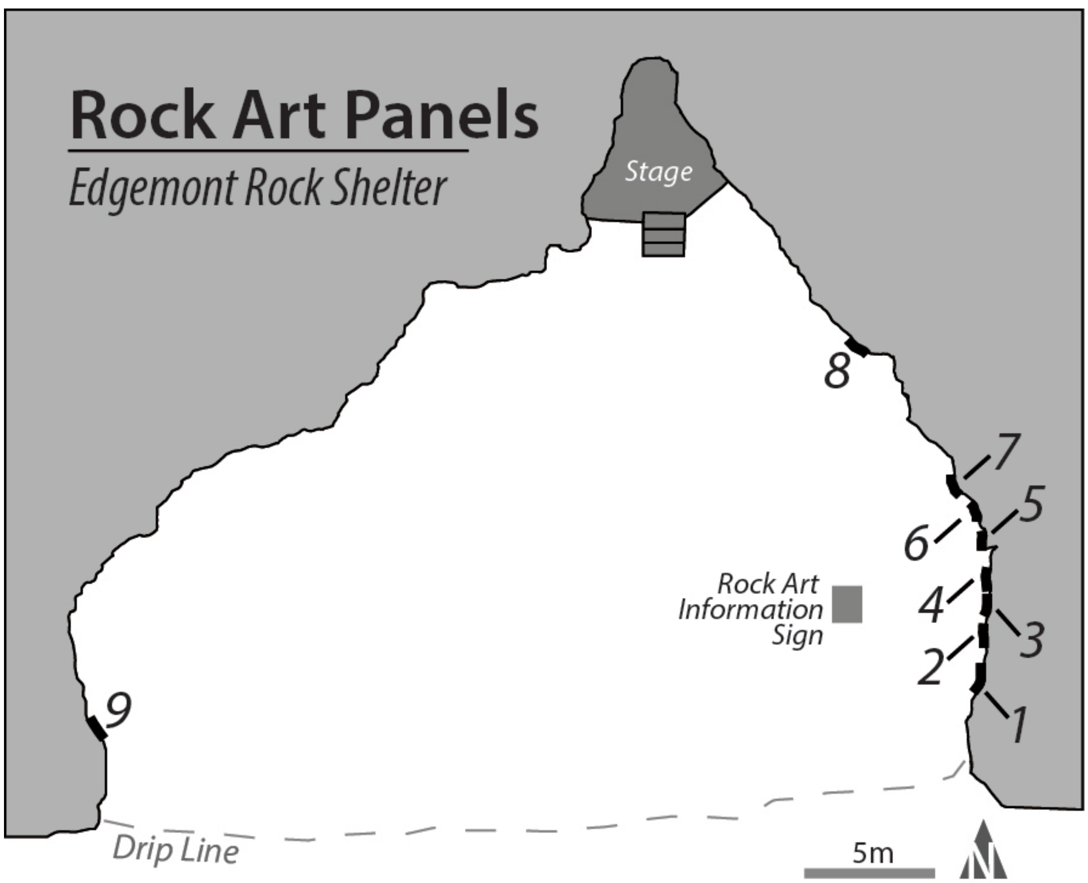


Figure 4.11: Map of the rock art panel locations within the Edgemont Rock Shelter. Note the small stage at the rear of the cavern and the informational placard directly in front of the main petroglyph wall. Map by author based on archaeological survey records with the permission from the Arkansas Archeological Survey, 2014.

Many of the artifacts discovered in the shelter are now on display at the resort's private museum open to the public and site access is not only easy, but promoted. Tourists and resort patrons are shown the shelter's location and encouraged to drive golf carts directly to its entrance. From the primary resort parking lot, a large sign leads visitors toward the "Indian Rock House Trail", where they can descend stairs down to the shelter. The shelter's private property status and remote location have hindered formal excavation and the petroglyphs have only been contextually dated to the late pre-historic. The University Museum historic photograph collections included images of Edgemont dating back to 1931, but archaeological records imply the site was not officially surveyed by the Arkansas Archeological Survey until the 1950s (Fritz & Ray, 1981).

Adding complications, at some point between 1950s and 1978 survey visits, approximately two meters of sediment and infill within the shelter was removed with a bulldozer—creating a more even floor and positioning the rock art beyond arms reach (Fritz & Ray, 1981). It has been speculated the exhumation was, in part, an attempt to safeguard the petroglyphs from the site's rampant vandalism issues. Nearly the entire shelter, along several surrounding caves and bluffs, are covered with carved or inked initials, dates, and names—some dated as old as 1900, making them historic in their own right. Some would argue the "legacy" generated by the widespread graffiti has created an unfortunate feedback loop: as more names are added to the walls, the higher the temptation for future vandals, almost producing a perception of "socially acceptable vandalism" (Whitley, 2001). To discourage further destruction, the resort erected a placard describing the petroglyphs and their historic and cultural significance, per the suggestion of the Survey (Fritz & Ray, 1981), but several engravings still emerge with modern dates—indicating vandalism is still a significant conservation concern. Limited documentation of the site required new panel designations for RASI, nine in total (Figure 4.11), and three photographs successfully were repeated.

RASI

The RASI analysis of the Edgemont Rock Shelter revealed a number of interesting and important decay processes impacting the site. Averaging 40.78 (*Urgent Possibility of Erosion),* the petroglyphs at this shelter scored fairly consistently between the *Urgent Possibility of Erosion* and *Problem(s) that Could*

Cause Erosion categories (Table 4.3). The relatively narrow variation among scores—lowest: 37 (panel 4) and highest: 44 (panel 3)—may suggest a certain degree of unilateral decay across the entire shelter. Despite featuring prominently in initial impressions of the site, vandalism and graffiti scored remarkably low in RASI, as most engravings tended to avoid areas with rock art or concentrate more near the shelter entrance—possibly supporting the resort decision to remove ground material from the shelter to protect the motifs. This is not to say vandalism is no longer a concern and some do intersect or obscure petroglyphs in the shelter, especially on the lone panel nine located across the shelter from the rest of the panels. However, although lowering the shelter floor may have discouraged future defacement of the petroglyphs, the resulting moisture and micro-environmental changes in the shelter may be responsible for exacerbating other natural decay processes, such as the rampant lithobiont activity devouring the site.

Indeed, lithobiont activity, particularly mosses and lichen, and subsequent decay processes all scored high in the site's RASI analysis. Several panels displayed evidence of both direct and indirect stone decay related to lithobionts. Most notably, practically every panel hosted some form of moss or lichen colony, some so densely that the petroglyphs are obscured and very difficult to identify. While the living colonies affect the visual quality of the rock art, when they die or are removed improperly they can cause further damage. Most panels in this shelter scored 2s and 3s on decay processes due to lithobiont detachment, such as "lithobiont release" and "lithobiont pitting"—when lichens and mosses remove stone material after death (Niccole V. Cerveny et al., 2007). The impact of lichen and mosses also goes beyond their lifespans in the form of secondary decay processes. Lithobiont digestion of stabilizing minerals and rock coatings leaves the stone surface weaker and less protected, facilitating the development of other superficial decay, such as granular disintegration, flaking, and loss of petroglyph detail—each of which RASI identified as significant issues at Edgemont.

Beyond superficial decay, the RASI analysis also classified some structural concerns within the shelter. Independent fissures—joints and cracks not constrained by lithology or bedding planes (Dorn et al., 2008)—scored relatively high on a few panels but are more pronounced across the cavern ceiling and surfaces nearer to the cave entrance. Some of these fissures transect the entire shelter and are quite large, providing shelter for birds and bats, which could be heard rustling and chirping throughout the entire assessment period. While the existence of the fissures may suggest inherent weaknesses in the substrate, the distribution of petroglyphs around the fissures may indicate they were already present prior to the rock art's application and not a primary threat. Other structural concerns highlighted in the RASI assessment include the development of tafoni—cavernous decay (Groom et al., 2015)—along with impending scaling and root wedging.

Edgemont Rock Shelter RASI Report			
Panel Number	RASI Score	Category	Major Issues
1	43	Urgent Possibility of Erosion	*Independent Fissures, Scaling, Moss, Lithiobiont Asctivity, Vandalism*
2	39	Problem(s) that Could Cause Erosion	*Independent Fissures, Flaking, Lithiobiont Activity, Moss*
3	44	Urgent Possibility of Erosion	*Lichen, Flaking, Granular Disintegration, Rounding of Petroglyph Edges*
4	37	Problem(s) that Could Cause Erosion	*Scaling, Flaking, Crumbly Disintegration, Lithobiont Activity*
5	42	Urgent Possibility of Erosion	*Scaling, Flaking, Granular Disintegreation, Rounding of Petroglyph Edges*
6	38	Problem(s) that Could Cause Erosion	*Moss, Flaking, Granular Disintegration, Lithobiont Activity*
7	40	Urgent Possibility of Erosion	*Flaking, Moss, Vandalism, Lithobionts, Rounding of Petroglyph Edges*
8	42	Urgent Possibility of Erosion	*Independent Fissures, Flaking, Undercutting, Vandalism*
9	42	Urgent Possibility of Erosion	*Weathering Rind, Flaking, Lithobiont Activity, Heavy Vandalism*
Avg:	40.78		

Table 4.3: RASI scores for each panel at the Edgemont Rock Shelter and primary concerns impacting that panel.

Repeat Photography

While the removal of the shelter floor made replicating the historic photographs more challenging, three were successfully captured. The observable differences between the historic and modern repeats are more significant at Edgemont than the other two study sites, primarily the result of bold chalking and prolific lithobiont development. As with many other petroglyphs in Arkansas, outlining motifs with chalk is evident in the old photos, however, at Edgemont, several motifs are now so obscured by moss and lichen that they can only be identified via comparison with the historic chalked images. Another factor increasing visual differences between historic and modern photographs is a higher complexity of motif designs, making loss of detail more visible than with simpler figures. It is worth noting there are some angular irregularities between historic and modern photographs as a result of floor elevation and topographic changes. A self-standing ladder was utilized to get closer to original camera height but restricted maneuverability limited repeat accuracy. Additionally, since lithobiont activity is so prevalent at this particular location, the repeat photos are displayed in color to more easily distinguish moss and lichen growth.

Depicting two different areas of the same panel (Panel 4), the first two repeat photographs displayed several of the same aesthetical and conservational issues so they were analyzed, and discussed, jointly. The first repeat displays the right end of the panel hosting two circular motifs along with

Figure 4.12: Left side: 1931 photograph of the upper right section of Panel 4 at Edgemont Rock Shelter with permission of the Arkansas Archeological Survey. Right side: Repeat photograph by author, 2014.

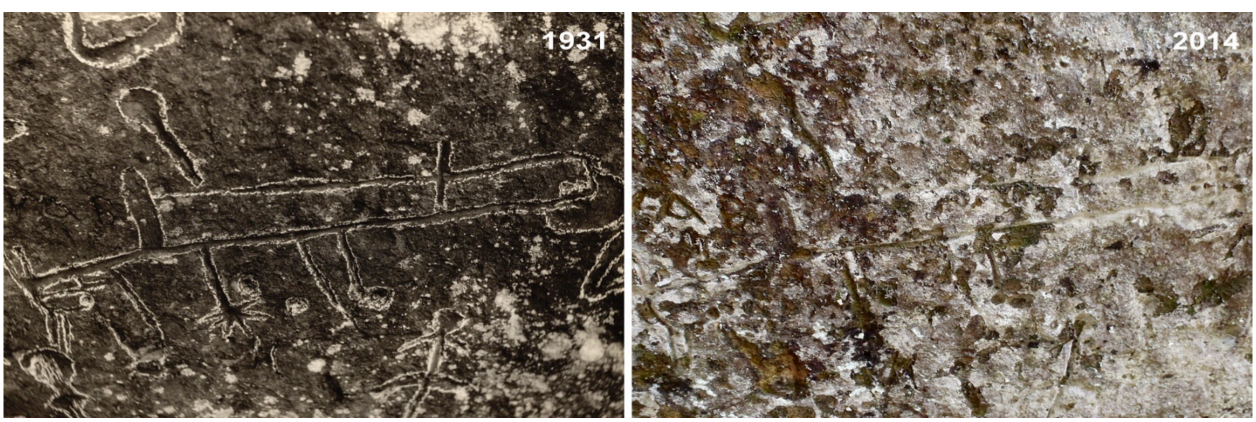


Figure 4.13: Left side: 1931 photograph of the lower left section of Panel 4 at Edgemont Rock Shelter with permission of the Arkansas Archeological Survey. Right side: Repeat photograph by author, 2014.

a couple of anthropomorphs (Figure 4.12). The small half moon-shaped outline on the far left of the image represents the beginning of the main subject of the second repeat photograph of left end: what appears to be a long-bodied quadruped above a small lizard and surrounded by other indistinguishable motifs (Figure 4.13). The most obvious change over time is the development of widespread lithobiont colonies now covering the majority of the panel. Although it is suspected the historic motifs would not be as clear without chalking, the panel surface in the older image noticeably clearer of lithobionts, particularly around the glyphs themselves and around the center of the photographs—the dramatic growth of the white lichen is the most noticeable. While the sepia coloration of the historic image may obscure evidence of mosses or other bio-coatings, the texture and uniform appearance of the panel surface suggests that at least some of host stone was still exposed in 1932—a statement that cannot be made for the modern repeats which are completely consumed by lithobionts. Not only are the petroglyphs now covered and harder to see, but, the biological degradation of the stone surface is also apparent in the repeat photographs, particularly in the more detailed elements such as the feet of the quadruped in figure 4.13 and the inner components of the left circular design in figure 4.12. With this decay showing through the biological coatings, it is suspected that the removal of the lithobionts would only cause further damage—which is often the case with lithobiont overgrowth (Whitley, 2001).

The final repeated photograph displays some of the more recognizable petroglyphs at Edgemont: a pair of large deeply incised kites/prayer stick designs on panel 7 (Figure 4.14). Each stick is roughly one meter in length and they are positioned high on the shelter wall, nearly on the ceiling, which complicated the repeat photography and required post-field photo manipulation to match angles between historic image and modern repeat. The deeper engraving of these glyphs may explain how they have maintained relative clarity and earned a moderate RASI score (40 = *Urgent Possibility of Erosion*): the deeper the motif the more the surround surface must decay to obscure the design. This is not to say there are not visual concerns for this panel. Much like the previous repeat pairs and representative of the site as a whole, the primary different in appearance is lithobiont growth and loss of details. While much of the surrounding stone surface is still visible in the modern repeat, there is considerable development of mosses and lichen within the carved elements themselves, such as the advanced colony of green moss in the upper spikes of the right prayer stick. Several sharp lines seen in the historic image now appear chipped or blurred, especially middle and lower sections of both motifs. Although it is currently enhancing motif clarity, the growth of lichen and mosses directly within the petroglyphs prohibits any kind of scientific dating or geochemical analyses of the rock art, which could be useful to determine the extent of mineralogical damage caused by lithobiont activities (Whitley, 2001).

Figure 4.14: Left: 1931 photograph of Panel 7 with permission of the Arkansas Archeological Survey. Right: Repeat photograph by author, 2014.

4.4 – DISCUSSIONS AND CONCLUSIONS

In general, all three rock shelters—The Narrows, Putnam, and Edgemont— scored relatively moderate RASI scores (upper thirties to lower forties), however, both RASI and repeat photography revealed unique case-specific decay processes and conservation challenges for each site. Despite rampant looting and heavy traffic, the counter-intuitively low RASI scores at the Narrows Rock Shelter, identifying surface decay and sedimentation as the greatest risks, were somewhat explained via repeat photography. The evidence of repatination and other potentially stabilizing geomorphologic processes seen in the modern photographs indicate relative stability—possibly suggesting a "looks worse than it is" framework for decay at this shelter. Alternatively, the extremely faded pictographs along the Putnam Rock Shelter exhibit both structural and superficial issues. Closer examination of repeat photography at this shelter reveals advanced decay and loss of motif detail, even in the 1930s image, providing a temporal context and suggesting the site has been in rough condition for quite a while. As one of the more interesting cultural resource management challenges, the petroglyphs within the Edgemont Rock Shelter have been overrun by lithobionts and vandalism, most clearly visible in the repeat photography. However, as the only privately owned and heavily advertised study site, the Edgemont glyphs are potentially held to a higher aesthetical standard and popular opinion requirements, which could lead to well-meaning but improper restoration efforts, which are often devastating to rock art's long term stability (McDonald & Veth, 2012).

When discussing the research results, it is essential to acknowledge the intentional variations in physical landscapes, management entities, geologic substrates, and temporal contexts, which discourage any form of direct comparison among the three shelters. The primary goal of this case study is not to characterize connections or patterns in rock art stability across Arkansas, but to begin the development of base-line assessments representative of the *diversity* of cultural stone decay processes and heritage management challenges faced by a critically under-researched state heritage and to test a duel-method research approach. To suit this purpose, the three study sites were deliberately chosen *because* of their divergent characteristics and rock art ages, which range from the 1400s AD to the late pre-historic (Sabo III, 2005c), and both RASI and repeat photography were employed at each site, with the applicability of such an approach under constant review throughout the research and analysis stages.

Although RASI is already a widely-recognized and effective rock art research and management tool (Allen & Groom, 2013a; Allen et al., 2017; Dorn et al., 2008), the supplementary combination of RASI with repeat photography demonstrated significant potential for advancements in rapid field assessments of rock art and cultural stone decay. To some scholars, repeat photography's fundamental limitations, such restricted access to historic photo archives and minimal empirical analysis technologies, disqualify repeat photography as a viable stand-alone research tool for rock art assessment beyond simple recording. However, this case study exemplifies how the applicability of repeat photography as a complementary method can be encouragingly advantageous. The additional information presented in the rephotography provided further evidence and explanations for unanticipated discrepancies in RASI scores and exposed time-dependent geomorphologic processes, such as repatination, which were otherwise undetectable by RASI's conditional "snap-shot" numerical methodology.

On top of the scientific benefit of the duel method approach, the general accessibility and visualization of landscape change of the RASI-repeat photography pairing provides easily understood and valuable information to conservation and heritage tourism management agencies, while also quickly identifying decay processes in need of further study. The three shelters assessed in this case study exemplify this benefit. Research analyses suggest the petroglyphs at the Narrows are more stable than they appear, so the U.S. Forest Service could afford to focus more attention on discouraging looting and other more pressing matters. The U.S. Corps of Engineers may be interested in knowing the Putnam pictographs have nearly vanished and perhaps they should conduct more research on how to protect the remaining motifs from water damage during high water events. At Edgemont, the visual quality of the petroglyphs is especially important since the site is marketed as a public cultural and tourism resource, so additional scientific investigations of the true impact of the lichen and mosses should be conducted well before any kind of cleaning or restoration is attempted to prevent further damage. Having the ability to present this information to management entities accompanied with visualizations of advancing decay and landscape change over time may serve as a more approachable and convincing method to incite the action necessary to conserve national heritage—such as the diverse Native American rock art sites scattered throughout the Arkansan Ozarks.

CHAPTER FIVE: CASE STUDY #2

Threatened Heritage:

Using Mixed Rapid Field Assessment Techniques to Monitor Potentially Impacted Rock Art in Grenada, West Indies

5.1 – INTRODUCTION

Relatively under-researched, the hundreds of petroglyphs colloquially called the Carib Stones on the island of Grenada represent some of the Caribbean's best examples of Arawak Amerindian rock art (1000 BC – AD 1400)(Crask, 2009). Two sites in particular, with easy access and dramatic motifs, exemplify Grenada's stone heritage and tourism management challenges: Duquesne Bay along the northwest Caribbean coast and Mt. Rich in the northern tropical rainforest. Both sites contain unique and visually dynamic rock art, and both sites have been heavily impacted by tourism development and attempted heritage conservation, with questionable results. For example, the main boulder containing rock art at Duquesne Bay, situated on a beach only a few meters from the sea, has been isolated and surrounded with retaining walls to keep sand from burying the glyphs. While sand is no longer a problem, the walls have poor drainage so precipitation and water runoff from nearby houses pool at the base of the larger boulder, where most of the petroglyphs are located, threatening their stability. Similarly, some of the more visible petroglyphs at Mount Rich, many motifs unlike any other on the island, have been "cleaned" by local activists, thus removing protective rock coatings, which usually help maintain geologic stability. These petroglyphs are now more noticeable from afar but to what extent has this trauma impacted the physical stability and decay patterns of the host stones? To address these issues, this chapter explores how rapid field assessment techniques can be used to monitor the success/impact of conservation efforts in *changing* rock art landscapes using Grenada's Carib Stones at Duquesne Bay and Mount Rich as a case study.

5.1.1 – Site Setting

Part of the mountainous tri-island nation of Grenada, Carriacou, and Petit Martinique, the main island of Grenada lies on the southern edge of the Lesser Antilles Island Arc (Figure 5.1), and is almost entirely volcanic, aside from a few off-coast coral reefs and consequent white sand beaches (Macpherson, 1973). The primary rock types of basalt and tuff, exposed in dramatic outcrops of lithified lahars and pyroclastic flows, andesite cones, and volcanic calderas, highlight the island's violent creation

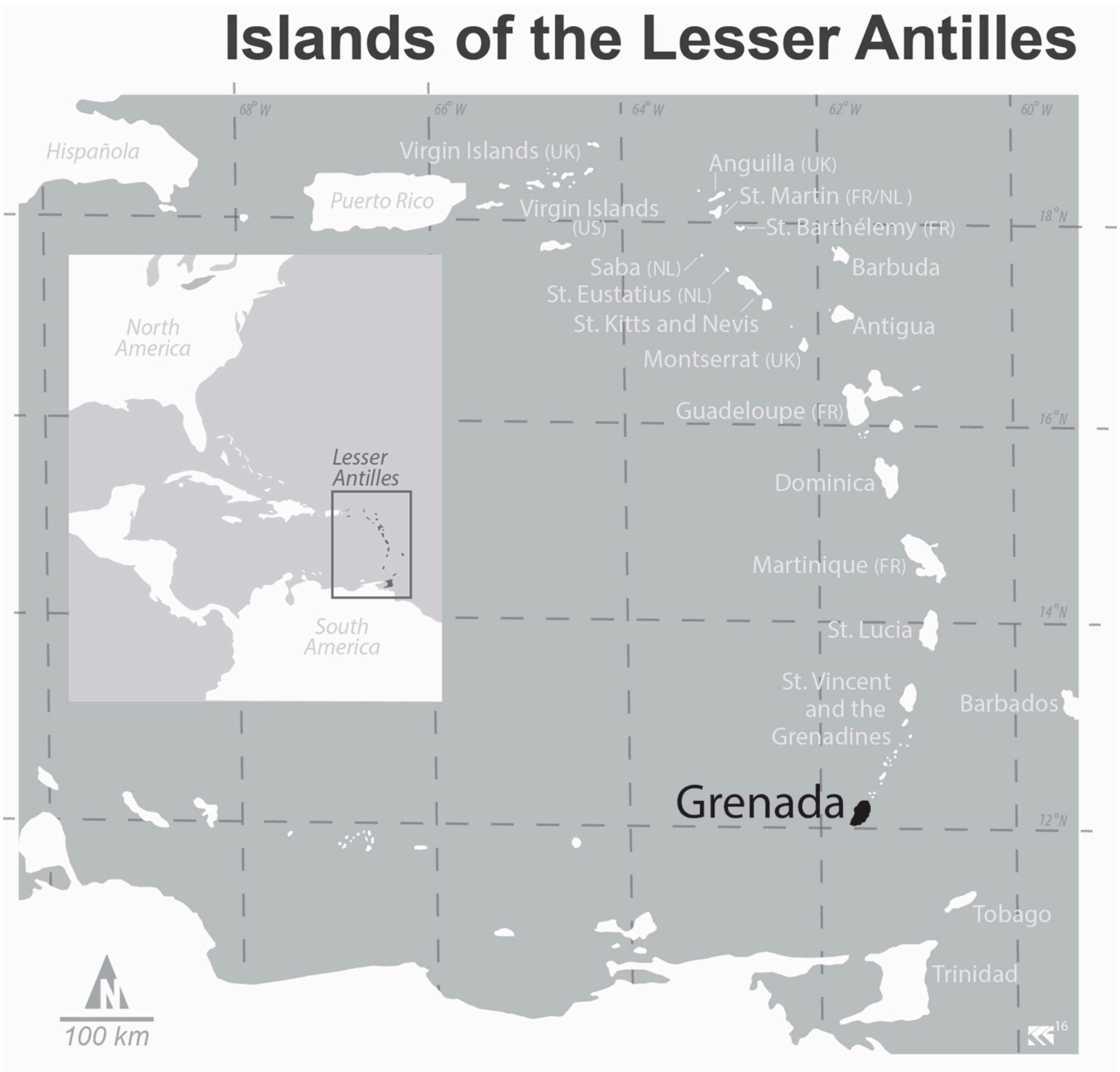


Figure 5.1: Regional map of Grenada within the Lesser Antilles island chain located in the southern Caribbean. Cartography by author, 2016.

(Arculus, 1976). In addition, small rounded granite stones can be discovered across the main island, particularly near known archeological sites. The contradiction of granite's intrusive formation and Grenada's extrusive landscape has lead some archeologists to theorize that these stones were brought to the island for trade between the different Caribbean nations, perhaps even used as tools for the creation of the Carib Stones themselves (Hayward et al., 2009; Marquet, 2009).

Despite being such a small island (only 19x34km), Grenada has a fairly varied climate ranging from tropical rainforest in the interior to salt ponds and scrub brush on the western coast, mangroves and swamps along the northern region to dry cactus-growing southern peninsulas. Larger global air circulation and Grenada's latitude heavily influence the island's diverse climate. Spanning 12 degrees north latitude bordering the Atlantic Ocean to the east and the Caribbean Sea to the west, the pronounced Northeast Trade Winds dominate the weather (Macpherson, 1973). The trade winds carry warm-moist air masses from the Atlantic (eastern) side, where it meets the island's mountainous interior. The winds force the air to lift orographically over 800 meters, resulting in the significant condensation and precipitation necessary to maintain the central rainforest. The now-dry air masses migrate back down to the Island's Caribbean (western) coast, creating a distinct difference in over-all rainfall patterns across the island, with an average of 350 cm rainfall on the windward side and interior but only 150 cm in the southeast lowlands. The Island's lower latitude also limits temperature variation with averages between 25˚C in January-February to 31˚C in July-August (Crask, 2009).

The fertile volcanic soils and steady precipitation have made the island particularly attractive for ambitious agricultural endeavors, greatly influencing Grenada's prehistoric and colonial histories. Evidence indicates that the Igneri Arawak Amerindians, some of first occupants of Grenada (1000 BC – AD 1200), were agrarian and utilized Grenada's favorable conditions to cultivate a variety of plants including maize, yam, calabash, paw-paw (papaya), and cotton (Crask, 2009). Although the rock art on Grenada are termed the Carib Stones, referring to a later tribe, contextual data and motif styles actually suggest the artists were more likely Arawaks. Around the turn of the first millennium AD, another Amerindian tribe migrated to Grenada and the Lesser Antilles: the Caribs, after which the Caribbean was named. Self-described as Kalinago, the Caribs were a warring tribe, famous for their fishing and boat making skills. Their ferocity as warriors may have also inspired the early European speculation that the

Caribs were practicing cannibals, though some scholars suggest the derogatory stigma may have been given to the Caribs as a means to justify their enslavement during the subsequent European colonization of region, which, for Grenada, began in the mid-1600s (Martin, 2013). Initially sought by the Spanish, British, French, and Dutch, Grenada ultimately came under British control leading to a colonial history fairly congruent with the rest of the region: failed native resistance, local and imported slavery, establishments of sugar plantations and rum distilleries, and a decimation of indigenous culture/heritage (Martin, 2013).

Figure 5.2: General locations of Duquesne Bay and Mount Rich on the main island of Grenada. Composed of three primary islands (Grenada, Cariacou, and Petit Martinique), the tri-nation state of Grenada is the southern most group of islands of the Windward Islands. Cartography by author, 2016.

Even in more recent history, Grenada's desirable location and environment have influenced their natural and stone heritage. Remaining British territory for many centuries, Grenada gained self-governance in 1967 and full independence later in 1983, following a failed coup and American intervention known as Operation Urgent Fury (OUF)(Crask 2009). The intervention itself has left its mark on the physical landscape in the form of bullet holes, bombed out buildings, and empty abandoned barracks across the island. The establishment of an independent government has allowed the island to begin constructing their own national identity and economy, the latter predominantly relying on fishing, agriculture, and tourism (Sinclair, 1987). To this day, Grenada exports more than a third of the world's nutmeg supply, earning it the nickname "The Isle of Spice" (Crask, 2009). However, the most potent economic force on the island is tourism. Endeavors to increase visitor revenue have included everything from constructing lavish all-inclusive resorts and installing a world-famous underwater sculpture park to "cleaning" petroglyphs and erecting paths and walls surrounding known rock art sites. Arguably, as the Grenadian economy becomes more and more contingent upon tourism, the stresses on their cultural/tourism resources, such as the Carib Stones, will become greater and the need for scientific monitoring of these resources all the more imperative to their long-term survival.

Depending on sources, the island hosts five (Marquet, 2006) or six (Dubelaar, 1995) main petroglyph sites, though there are several more archeological sites with cupules, or grinding stones, in nearby boulders. This study focuses on two of the most visited sites: Duquesne Bay and Mt. Rich (Figure 5.2). Rock art itself is categorized into four overarching types: petroglyphs, or images pecked into the rock; pictographs, or painted images; geoglyphs, or rock alignments; intaglios, desert pavement scraped away to reveal non-varnished surfaces beneath (Whitley, 2005). The rock art on Grenada are entirely petroglyphs, meaning they were pecked, and in some cases incised, into the Island's dramatic basaltic boulders.

5.1.2 – Existing Rock Art Research in Grenada

Representing one of the largest concentrations of West Indian rock art, Grenada's Carib Stones are surprisingly sparsely researched. Consistent with the designs and engraving techniques of rock art found throughout the Greater and Lesser Antilles, most scholars suspect Grenada's Carib Stones were created by common inhabitants during the Pre-Contact era (AD 900-1100)(Dubelaar, 1995). These dates are merely speculated and have never been scientifically confirmed due to harsh environmental conditions and a general separation of rock art sites from lithic/artifact producing sites, which are more easily dated (e.g. Bullen, 1965). Formal dating of the petroglyphs could add a new dimension to the Island sites' context. Only a handful of academic and scholarly parties have officially surveyed select individual petroglyphs and motifs of Grenadian rock art periodically since the early 20th century (cf. Dubelaar, 1995; Hayward et al., 2009; Hedges, Cover, & Man, 1990; Huckerby, 1921; Marquet, 2009). In many cases, any attention given the rock art is as side notes or brief mentions in the more prevalent traditional field archeological investigations of the Island's excavated Amerindian burial and residential sites (e.g. Cody, 1992).

Even more distracting, many archeological records and local guides confuse cupules, or grind stones, as being synonymous with petroglyphs despite entirely different creation processes and function (e.g. Cody, 1992) or only address the social significance of the rock art, completely disregarding the physical stone itself (e.g. Torres, 2013). Aside from two reports (Allen & Groom, 2013a, 2013b), scientific analyses of the Carib Stone's physical conditions or geologic stability have been sorely neglected. Even Allen and Groom's (2013a; 2013b) assessments only incorporated a single dataset, so although they provided critical baselines for further investigations, their results are static and do not reflect Grenada's rapidly changing landscape. A more longitudinal monitoring study—such as that presented here—can help provide the temporal context missing from Allen and Groom's (2013a; 2013b) original geologic assessment and address the geologic impact/effectiveness of local interventions and conservation efforts.

5.2 – CASE-SPECIFIC METHODS

Similar to the previous case study, both RASI and repeat photography (see Chapters 3.3 and 3.4 for method specifics) were utilized to assess the Carib Stones, although with a slightly different focus and timeline. In the Arkansan Ozarks, RASI was paired with repeated historic photographs to create a base-line, or snap shot, of rock art decay representative of the diverse conservation challenges in the region. This case study in Grenada has a more temporal agenda, focusing more on contemporary issues and monitoring landscape/decay changes over time, ultimately requiring multiple datasets for each site accumulated over a selected period of time. To fit this need, RASI and repeat photography datasets were collected from the annual University of Colorado Denver study abroad program *Sustainability in the Caribbean*, conducted every May from 2012-2016, except 2014 when a different research topic was pursued. One of the core foci of the program is cultural tourism and resource management, utilizing RASI as an effective pedagogical tool (Allen, 2008).

Although different groups of students assessed the stones each year, consistent training and supervision by the program's permanent instructors—both RASI experts—along with post-collection adjustments where necessary help maintain moderate experimental control and minimize user error/researcher biases when analyzing differences between datasets. Additionally, RASI has been statistically validated to display insignificant differences among individual scores despite researcher background, previous knowledge, or specialty (Cerveny, 2005; Dorn et al., 2008). Therefore, variances in RASI scores for Grenada's Carib Stones from 2012-2016 are, with a certain degree of confidence, interpreted as actual changes in the landscape/panel stability and not discrepancies in data collection. Analyzed RASI panels correspond with those identified by Allen and Groom (2013a; 2013b) with minor adjustments at Mount Rich, which will be discussed in greater detail in the Mount Rich analysis.

Along with RASI, panel and contextual photographs were also repeated each year, providing further control/validation of RASI scores as well as visualize measured change. Historic repeat photography is typically displaying in grayscale to minimize visual confusion between grayscale historic photographs and colored modern repeats (cf. Webb et al., 2010). However, since the repeat photography for this case study only involves modern repeats, and distinctive color/rock coating alterations are among the most prevalent landscape changes over the years, repeat photography groupings will be displayed in color. Despite slight visual differences due to varying time of day and lighting conditions when the photographs were taken, limited photo editing or digital manipulation will ensure the most accurate depictions of the rock art panels and rock coating color quality for each year. In most cases repeat photography dates match RASI collection dates, however insufficient 2012 photo quality at Duquesne Bay required their replacement with older images from 2009, which is clearly marked in each image.

5.3 – RESULTS AND ANALYSIS

Spanning the temporal context of this study, the results of each site will be discussed individually, giving special attention to rock decay patterns/changes over time as well as the potential impact of conservation efforts, both beneficial and damaging. Duquesne Bay, with a more passive conservation/management history, will be discussed first, followed by Mount Rich, of which local intervention has been much more direct. General landscape changes, as well as possible future research and policy alterations, are then presented in the final sub-chapter.

5.3.1 – Duquesne Bay

Situated on Grenada's Northwest coast, the three rock art panels at Duquesne Bay are limited to two boulders, only separated from the Caribbean Sea by a small beach (Figure 5.3). Local self-declared "caretakers" often tell of additional petroglyphs that have since been buried by sand—somewhat plausible as the two main motifs (panels 1 and 2) are currently below beach sand levels. During the 1990s, the Government of Grenada partnered with the Grenada Historical Society to excavate the sand around the boulder to expose the rock art, predominantly at the base of the panels, and erect cement retaining walls to prevent future infilling (Martin, 2007). Despite the best of intentions, wastewater and runoff from the nearby houses and ridgeline now pools at the base of the rock art panels, as the retaining walls lack efficient drainage—although there have been recent government efforts to remedy this issue. This has caused considerable damage to the petroglyphs, especially the intricate carved faces and god motifs at the base of main boulder—damage reflected in each panel's RASI score. The third panel, several meters from the main boulder and retaining wall, is unique among Grenada's Carib Stones, as it is carved around the corner of a small rectangular boulder. Assumed to have fallen since the creation of the petroglyph, the host boulder is wedged precariously between two neighboring boulders and an Indian almond tree, with the rock art panel on the underside facing the ground. The presumed movement of the host boulder presents concerns of past and future undercutting, which are echoed in the panel's average RASI scores.

In addition to the petroglyphs, there are several surrounding boulders containing cupules (grind stones), some housing as many as twenty-two divots. Proximity of these boulders to the Sea has been their primary threat, as many are partially submerged—some entirely inundated during high tide—and covered with barnacles and other crustaceans. Regardless, the site's cupules were simply recorded and mapped by Allen and Groom (2013a; 2013b), and not evaluated as part of either study as the focus has primarily been the site's petroglyphs—as with this case study as well. Notwithstanding, they are still considered stone heritage at Duquesne Bay and worth mentioning.

For the analysis, all three panels were RASIed all four years (2012, 2013, 2015, and 2016). The scores were then tallied and compiled in a spreadsheet displaying the average final scores and overall site score for each year (see Appendix E). In addition, four photographs were repeated every year including one close up view for every panel and a contextual shot of the main boulder and retaining wall. As stated previously, repeat photographs are presented in color, since they are all modern photographs and differences in rock coating can be significant over short periods of time.

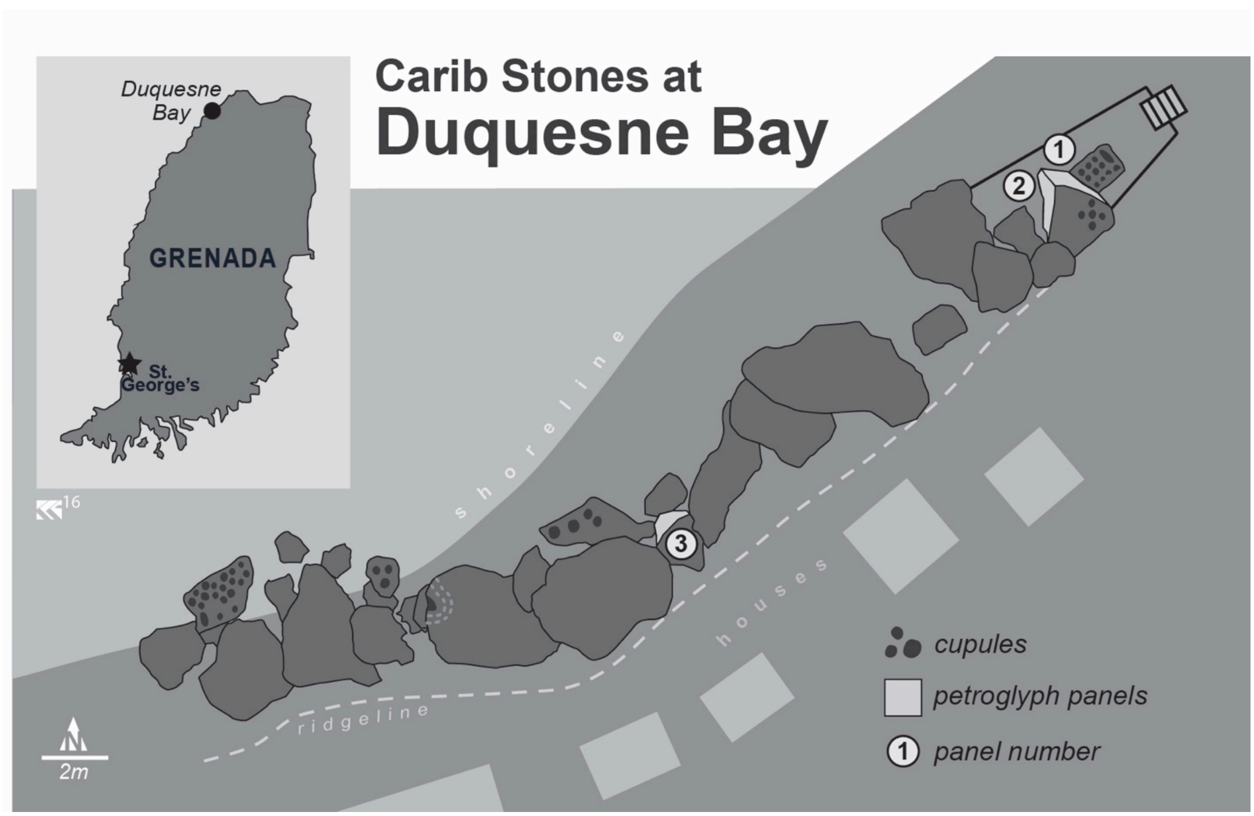


Figure 5.3: Rough field map of the rock art panels and cupules at Duquesne Bay, Grenada. Cartography by author, modeled after (Allen & Groom, 2013a), 2016.

RASI

Throughout the years, the overall average site scores have remained relatively stable, with only a 2-point difference across all four assessed years—consistently hovering near the lower end of the *Great Danger of Erosion* descriptive category (Figure 5.4). General trends suggest the two main panels (panels 1 and 2) have barely changed, with a very slight stabilizing trend, straddling the line between the top two qualitative categories, possibly due to the current endeavor to drain the stagnant water that pools at the base of the host boulder. Alternately, RASI scores for the third panel identify an upward trend suggesting the panel has become increasingly unstable. To explore these patterns in more detail, each boulder (not panel) will be analyzed individually for this site (i.e. panels 1 and 2 will be assessed as a pair and panel 3 will be discussed separately).

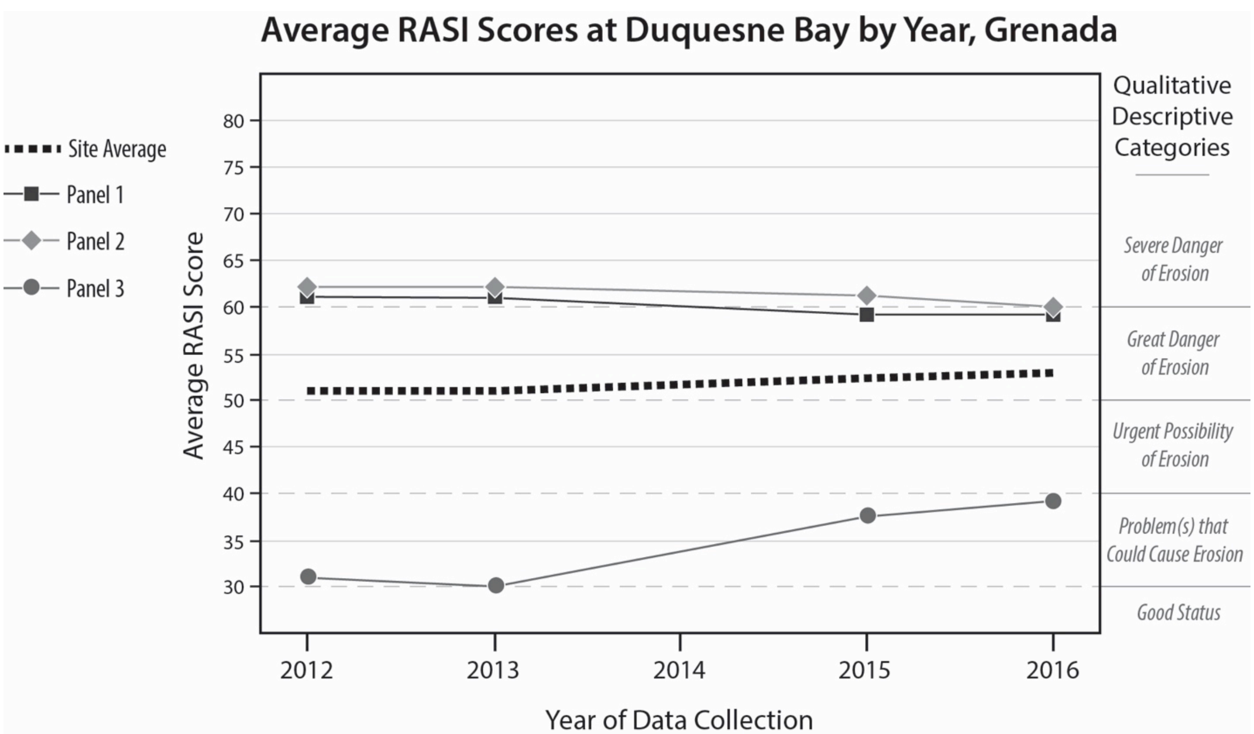


Figure 5.4: Graph of yearly average RASI scores for each panel at Duquesne Bay with implied decay patterns shown via lines between individual scores. The total site average score, displayed as the black dotted line, shows little change over the years.

As expected, many of the threats and decay trends identified for the main boulder are related to the presence and movement of water, whether run off from the adjacent ridgeline or stagnant water collecting around the base of the retaining wall. Mostly superficial, the main threats remain abrasion (steadily increasing), granular disintegration (consistently high), and lithobiont activity—with changes in lithobiont- and fissure-related RASI elements identifying a possible decay feedback loop. Gradual expansion of the shallow independent fissures transecting panels one and two allows increased lichen and moss growth within the fissures, resulting in higher instances of lithobiont release, concentrating water movement and decay along the occupied fissures, potentially exacerbating fissure decay. The culmination of these processes has lead to a steady decrease of petroglyph clarity, as noted in a marked rise in the RASI element *Rounding of Petroglyph Edges*, especially on panel one, where one of the two elaborate carved faces is nearly indistinguishable. Unstable surfaces and abundant water has also lead to the accumulation of various different algae, lichen, and other potentially influential—beneficial or not—rock coatings across both panels (Figure 5.5). Despite these threats, counteracting stabilization of other decay processes has kept changes in the overall boulder's scores minute. In particular, salt-related RASI elements, such as splintering (both developing and occurred), flaking, scaling, and efflorescence/subflorescence, have all declined.

Exhibiting a greater degree of change, RASI scores for panel three suggest a general decrease in stability, particularly in terms of contextual and inherent weakness concerns. Panel three's precarious setting appears to be worsening, with RASI scores indicating increasing risks from undercutting (particularly when paired with concerns of piping and slope instability surrounding the host stone) and plant life—both from widening roots threatening to topple the stone and root/plant growth adjacent to the panel. The diminishing beach at Duquesne Bay has also decreased the distance of the low hanging petroglyph with the Caribbean Sea and corrosive salt water, a risk reflected in side notes and *Other Concerns* in the impending loss category. Textural issues, both structural and superficial, along with decreasing levels of protective rock coatings and case hardening, suggest a potential weakening of the host stone that could present more problems in the near future. It is important to keep in mind that even though scores for panel 3 have steadily increased over the last 5 years, they still remain considerably

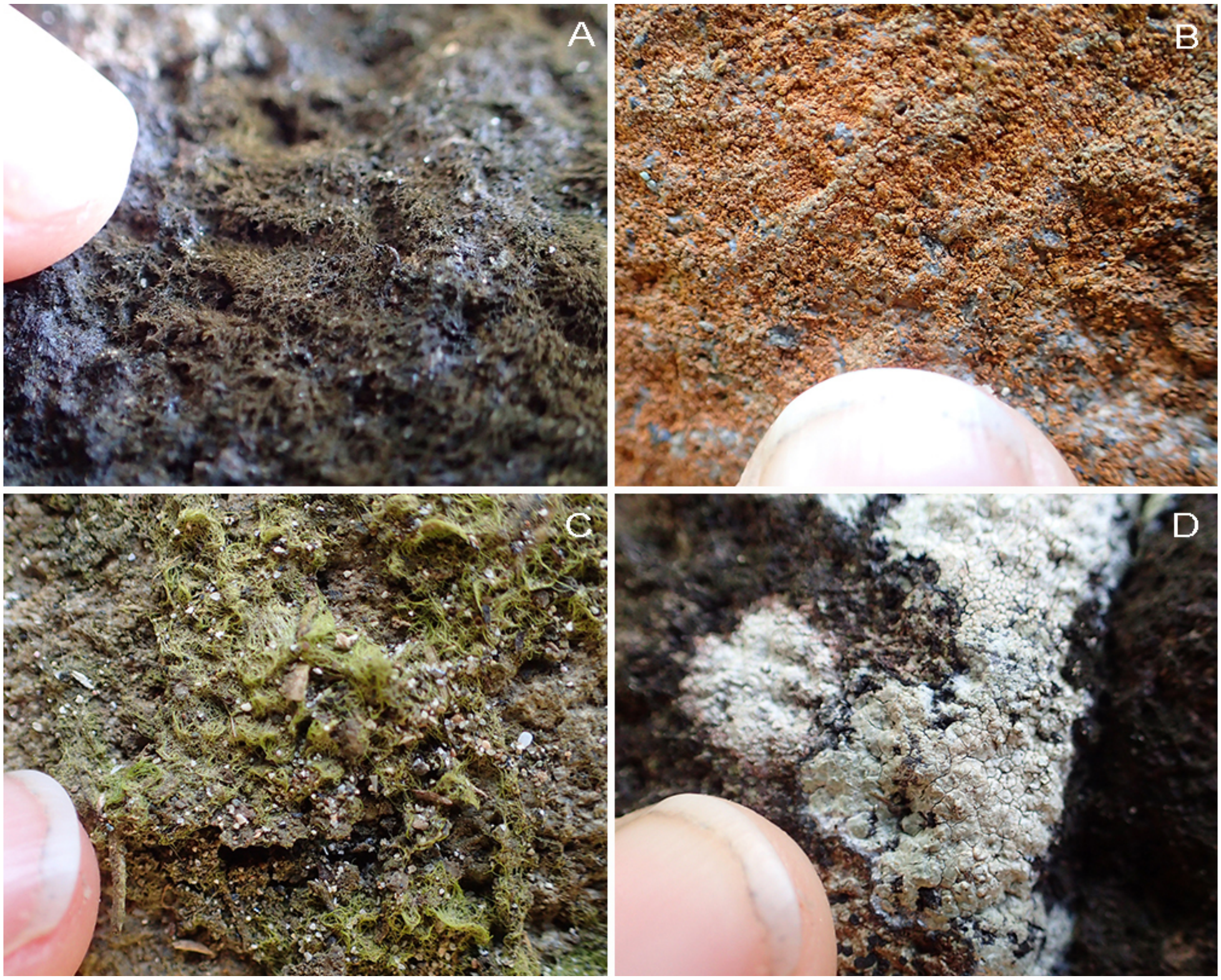


Figure 5.5: Various lithobiont growth on panel 1 at Duquesne Bay. Both texture and color differ among the coatings, ranging from furry light green or brown in images C and A to fine orange and yellow lichen/marcobacteria in images B and D. Further investigation is necessary to determine the species and morphology of the species but their coexistence on one panel is worth noting. All photographs by author, 2016, shown in color for better differentiation.

lower that those of panels one and two, staying within the second lowest descriptive category of *Problem(s) That Could Cause Erosion*, only recently approaching the upper limits of this category.

Repeat Photography

Representing the setting of the two primary panels at Duquesne, the contextual repeat photographs for the main boulder provide a longitudinal view of the retaining wall's impact on the site's stability (Figure 5.6). Time of day and changes in shadows from surrounding foliage may account for some visual difference, but wicking, sedimentation, run off/abrasion, and stagnant water are only some of the issues identified in these photos. To determine the visual extent to which these issues may have impacted the individual motifs, more in-depth repeat photographs were taken of the primary petroglyphs on each panel.

Up close repeat photography for both panels one and two illustrates many of the concerns already acknowledged during the RASI analysis, such as changes in lithobiont activity and loss of petroglyph detail. Panel one, with the added advantage of a longer displayed timeline, demonstrates the dramatic detail loss of the right decorative anthropomorph due to increased granular disintegration, flaking, and lithobiont activity (Figure 5.7). Additionally, the RASI-identified differences in rock coating are revealed as not only a general darkening of the stone surface, but also the development of different types of coatings, some beneficial, such as the dark stone patina, and others potentially damaging, such as the spreading orange algae in the center left of the 2016 photograph.

Figure 5.6: Repeat photographs of Panel 1 at Duquesne Bay from 2009 to 2016. All photographs provided by Casey Allen except 2016 (by author).

Figure 5.7: Close up repeat photographs of the two primary motifs on Duquesne Bay Panel 1 from 2009 to 2016. All photographs provided by Casey Allen except 2016 (by author).

These themes continue through to panel two on the other side of the boulder (Figure 5.8), illustrating an even more intimate relationship with the stagnant water that influenced so much of the panel's RASI analysis. While water/sand lines are clearly visible on panel one (the differently colored bands running horizontal across the panel's base), a slight tilt of the host boulder leaves the motifs on panel 2 more vulnerable to direct contact with standing water—as seen is the case in all four photographs. While these less-detailed motifs are not as decayed as their counterparts on panel one, the dark wicking line across the panel (most prominent in 2013 and 2016) and algal growth along the base of the panel might suggest significant water and, likely, dissolved mineral movement throughout the stone, potentially explaining the panels slightly higher RASI score for flaking, scaling, and splintering—which can each be associated with subsurface mineral accumulation (Mol & Viles, 2010; Wedekind & Ruedrich, 2006).

Figure 5.8: Close up repeat photographs of motifs on Duquesne Bay Panel 2 from 2012 to 2016. All photographs provided by Casey Allen except 2016 (by author).

These decay processes may also account for the slight indent at the base of the boulder, where decay might be more concentrated. The minor changes in the surrounding soil line and visible debris may also indicate more that just water can become trapped behind the retaining wall, presenting yet another reason to improve the current infrastructure at the site.

Earning much lower, albeit increasing, RASI scores, the repeat photographs for panel three only reveal minor changes in the panel's textural appearance and algal rock coating, though differences in lighting may account for some of the color variability (Figure 5.9). The green paint, noted in each year's RASI assessment, is clearly visible on the motif's lips and around the headdress, though it is most prominent in the 2015 image. Intense dust coatings and spider activity may account for some of the rough "pocky" texture displayed in the images, but, in general, changes among the photos is relatively minimal. With relatively low RASI scores, few visual changes were expected, however, in this instance, the limited

Figure 5.9: Close up repeat photograph of the bi-angle face on Duquesne Bay Panel 3 from 2012 to 2016. All photographs provided by Casey Allen except 2016 (by author).

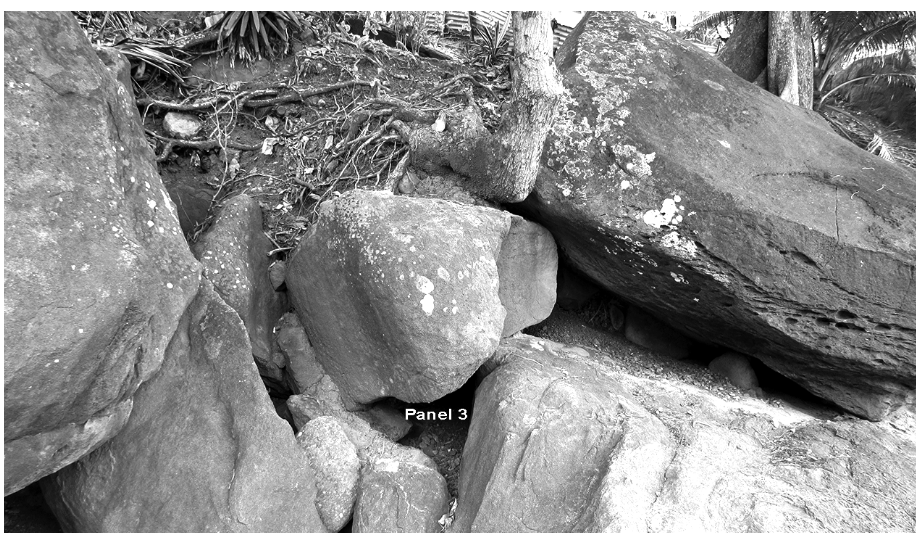


Figure 5.10. Contextual view of Duquesne Bay Panel 3's toppled boulder and surrounding landscape. The beach is barely beyond the image's scope directly below the panel and the road and more houses sit on the hill above. Photo by Casey Allen, 2016.

view-shed of the repeated photographs may be ignoring wider contextual issues known to be impacting the panel. When viewed from a distance, larger threats to the panel, such as plant growth and undercutting, become more easily recognized (Figure 5.10).

5.3.2 – Mount Rich

Representing the most researched rock art on Grenada, the Mount Rich petroglyphs rest at the bottom of a steep ravine (~50% slope), though some suspect they may not have been created there. While the three petroglyph-containing boulders are now directly in the path of the frequently flooding St. Patrick River, some scholars speculate the primary boulder, hosting panels 4-9, was actually located higher up on the edge of the ravine and slide down to its current position in the recent past (Allen & Groom, 2013a; Hanna, 2016). This suspicion is partially based on major differences between the stone's current location and that portrayed by Huckerby (1921) in his early exploration of the Carib Stones, where he describes the boulder as being surrounded by "dense cocoa cultivation" (p. 59)—which can be found higher uphill—and several of his plates depict the boulder in what appears to be a slightly different position and angle (Hanna, 2016), but there is not enough context within the viewshed of the image to confirm this. Additionally, there are several petroglyphs now wedged against another boulder, in an impossible position for them to have been created in situ. Further confirmation from local sources also suggest the boulder may have fallen fairly recently, as late as the 1960s or 1970s, possibly the result of a number of hurricanes and tropical storms that have impacted Grenada's landscapes in the past century (Sinclair, 1987).

Although the fall into the ravine has made Mount Rich's rock art less accessible, they remain academically and culturally important—inspiring ongoing international research. For decades, archaeologists have had interest in the site's Carib Stones for their unique setting and intricate motifs—such as the only "big cat" petroglyphs in the Lesser Antilles, possibly created as "remembrance glyphs" of the wild cats from the Carib/Arawak's origins in Venezuela, where similar motifs can be found (Allen & Groom, 2013a; Dubelaar, 1986; Whitley, 2001). The uniqueness and diversity of motifs at Mount Rich even inspired Cody (1990) to add a fifth category—"zoomorph"—to her widely-used petroglyph classification system to catalog much of the Caribbean's rock art (Martin, 2007). Allen and Groom (2013a) were the first to ever assess the physical condition of the host boulders at Mount Rich, but while this provided a valuable base-line assessment, the study's static dataset limits its ability to represent a dynamically changing landscape, where local management is periodic at best.

The site's historic and touristic significance has motivated a number of local endeavors to protect and manage the Mount Rich rock art, although many of these efforts are not always collaborative with nor

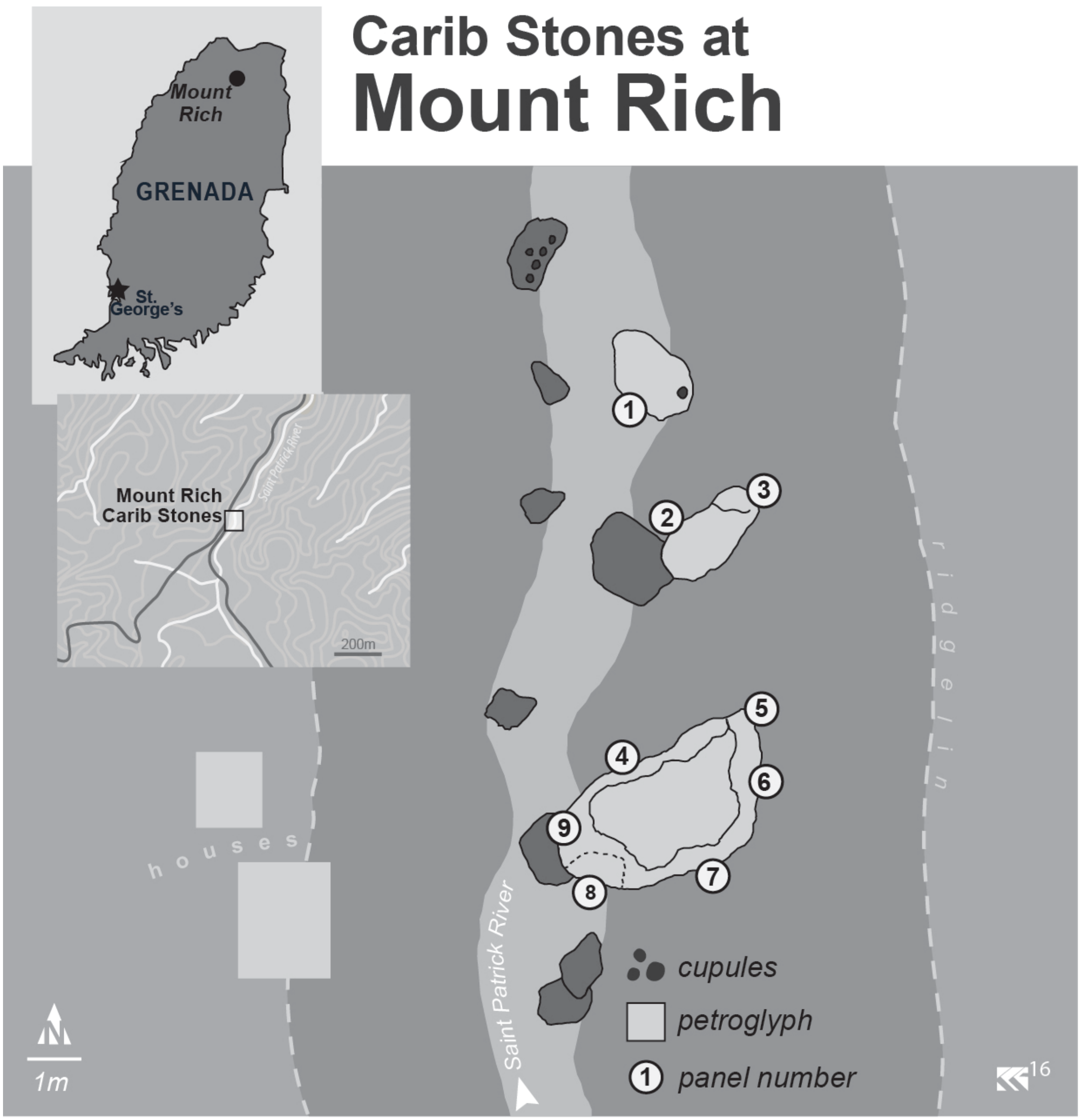


Figure 5.11: Rough field map of the rock art panels and cupules at Mount Rich, Grenada. Cartography by author, modeled after Allen and Groom (2013a), 2016.

sanctioned by the appropriate governing parties. For example, Grenada's Market Access & Rural Enterprise Development Program (MAREP) has been working the last few years to develop a conservation/tourism program and establish an information center located on the ridgeline above the site, but have so far only restored an abandoned building overlooking the site. Despite their intentions to develop the site for the Island's vital tourism industry, they remain decidedly disconnected from the rock art itself (Boney, 2016). Similarly, several local agencies, such as the Grenada National Trust and Ministry of Tourism, have expressed desires to conserve and manage the site, but either funding or personnel inadequacies have limited any kind of official intervention. Perhaps frustrated with the lack of progression, a group of unidentified members of the local community took action in spring 2015. Later disapproved by the Ministry of Tourism (Jessamy, 2016), the group cut down nearby vegetation, cleared surrounding debris, and "scrubbed" many of the more visible petroglyph panels—in many cases completely removing the stone's rock coatings and leaving behind distinctive scour marks and scrub lines. While these individuals may have had the best of intentions, the lasting impacts of their actions on the site's long-term geologic stability is unknown.

Having experienced more intrusive conservation efforts than Duquesne Bay, changes in the longitudinal RASI and repeat photography assessments at Mount Rich can help reveal the nature and extent of any damage/benefit from the community's unauthorized "intervention". Nine total panels were assessed using RASI—using the same panel designations as Allen and Groom (2013a; 2013b) except combining panels 9 and 10 to reduce redundancy and motif overlap (Figure 5.11). The first two datasets, 2012 and 2013, precede the site's cleaning by a few years, the 2015 dataset was collected days after the event, and the final dataset, 2016, was nearly a year and a half afterwards. Repeat photography was also heavily used at the site to help visualize the aesthetical impacts of the intervention. Eight photograph groupings were successfully repeated, including some with only images from 2015 and 2016, to assess panel "recovery" post-scrubbing.

RASI

Average site scores, as well as average panel scores, exhibit relatively steady decay rates the first two years, a dramatic spike in all scores in 2015 following the cleaning, and then a decrease in

RASI—though only a few reached the same or below their original scores pre-clean (Figure 5.12). That said, the most recent overall site average appears to have returned from the highest descriptive category, *Severe Danger of Erosion*, to only slightly above its earlier levels: bordering the threshold between the second and third lowest categories, *Problem(s) that Could Cause Erosion* and *Urgent Danger of Erosion*, respectively. Interestingly, the post-clean scores are more concentrated and similar to each other than in previous years, opposite of the previous year when scores were the most diverse. Possible causes for this may be the simultaneous exposure of raw stone across the panels now being more universally vulnerable to rock decay processes, whereas the year before, some panels were scrubbed harder and more thoroughly than others—thus the wider gap in scores. However, not all panels were cleaned, and a few actually show improvement after the community intervention, therefore, each panel or similar panel groupings are discussed separately.

Scoring significantly differently than the main boulder, the smaller stones housing panels one, two, and three seem the most unaffected and/or benefited by cleaning the site/stones. For example, the average score for panel one fluctuates dramatically—unlike any of the other panels—although this could be explained by the panel's precarious location within the riverbed. Situated on a low-lying boulder directly in the path of the St. Patrick River, the single glyph on panel one is extremely faint and often completely inundated, making the RASI scores particularly concerned with river behavior and water levels, highlighting such processes are abrasion, granular disintegration, and rounding of petroglyph edges. The years that panel one scored noticeably higher correspond with generally wetter years with higher river levels, making threats to the panel more immediate. The farthest from the main boulder, panel one was mostly unaffected by the site's cleaning in 2015, with RASI scores displaying little difference between pre- and post-clean scores.

Possibly the only panels to actually benefit from the local intervention, panels two and three represent the only panels to earn lower post-clean scores than previous years—panel three most significantly (see Figure 5.12). While both panels display overall improvement, differences in longer-term patterns suggest very different responses to the site's cleaning. Located on a smaller boulder tucked into the west bank just south of the main boulder, examining these differences in more detail provides clues as to what actions might have been the most beneficial for panel stability. The pre-clean scores for panel

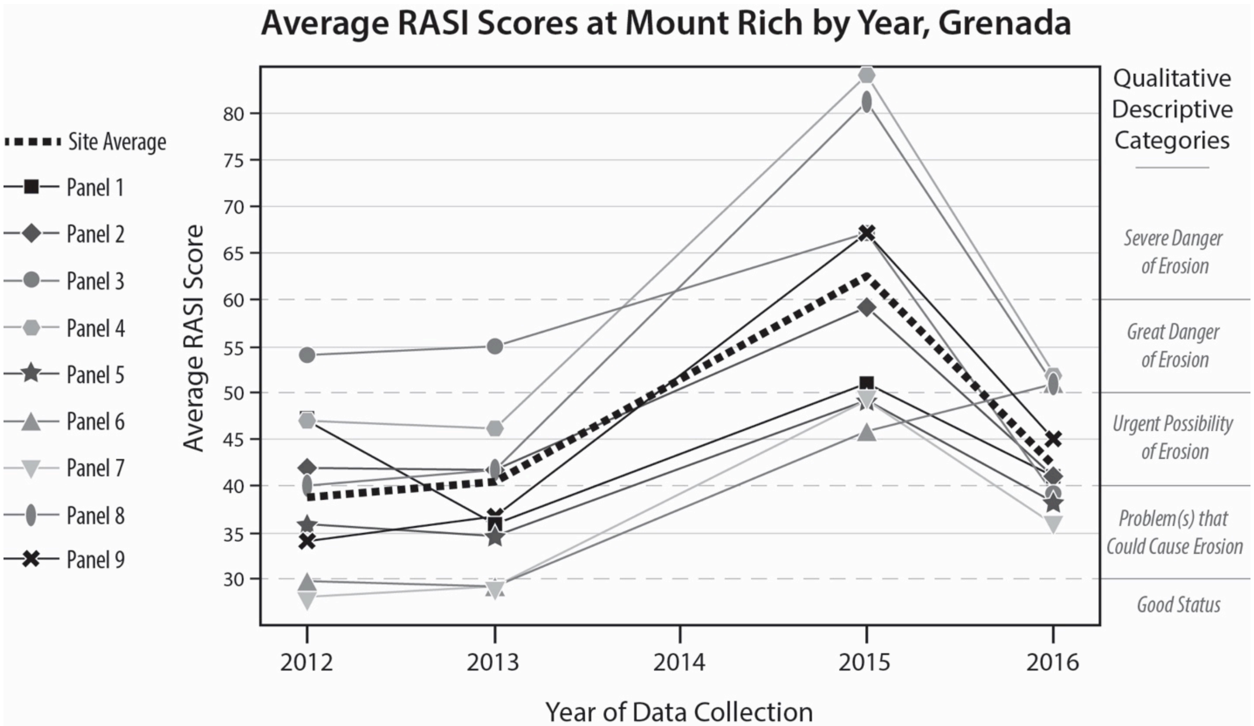


Figure 5.12: Graph of yearly average RASI scores for each panel at Mount Rich with implied decay patterns shown via lines between individual scores. The total site average score, displayed as the black dotted line, highlights the significant spike in RASI scores directly following the 2015 cleaning and the perceived recovery the following year.

two are fairly stable with primary issues being independent fissures, fissuresol development, rounding of petroglyph edges, and lithobiont activity. Conversely, panel three was exhibiting higher and increasing RASI scores, with growing concerns regarding plant growth near the panel, flaking and scaling, abrasion, and loss of rock coatings. Both panels exhibited a spike in RASI scores for 2015, as did all the other panels, but visual observations testify that even though vegetation and plant debris was cleared from around both panels, only panel two—with its more intricate motifs—was scrubbed, leaving panel three mostly untouched. This discrepancy is reflected in RASI scores with generally higher rates of textural weaknesses, abrasion, and rock coating detachment for panel two not seen as clearly for panel three. However, the post-cleaning 2016 RASI scores show the most significant difference, with panel three scores dropping below panel two for the first time in record. A possible reason behind this dramatic stabilization is that clearing the area around the panel, but not cleaning the panel itself, eliminated some of the major threats impacting panel three (i.e. plant growth near panel and soil abrasion) without introducing new traumas to the panel's surface. While panel two stabilized as well, scores only barely fell below its initial pre-clean levels. Benefits from clearing debris from the area were potentially countered due to new or worsening issues introduced to the panel when it was scrubbed, such as increased textural anomalies, weakened stone developing a weathering rind, and general loss of petroglyph detail.

Many of the stability issues highlighted in the smaller boulders' RASI scores are amplified in those of the larger primary boulder housing panels four through nine—the only petroglyphs visible from the road above and thus cleaned more vigorously. Almost all of the main boulder panels are now at least one qualitative category higher than they were pre-cleaning. Slight patterns in scores suggest that panels displaying stabilization between 2012 and 2013 (i.e. panels four, five, and six) were able to recover more effectively than those exhibiting destabilization (i.e. panels three, seven, eight, and nine). This pattern appears consistent regardless of the severity of pre-cleaning decay. For example, panels four (stabilizing 2012-2013) and eight (destabilizing 2012-2013) are both on the higher end of scores for the site, both experienced the most significant trauma during the cleaning, and yet post-clean 2016 scores are nearly identical, with scores relatively close to panel four's pre-cleaning scores but several points higher than panel eight's previous values. This is also the case for panels five and nine on the lower end of RASI scores: similar scores pre-clean with one increasing and the other decreasing, trauma in 2015, more complete recovery for decreasing panel—in this case panel five. However, other factors are also at play here, such as the significant locational differences between the two panels: panel five is tucked away on the backside of the boulder while panel nine is the main panel visible from the road and cleaned more rigorously, as seen in the dramatic spike in the panel's average score in 2015 compared to panel five (see Figure 5.12). Of all the panels at Mount Rich, only one scored higher post-clean than the initial cleaning of 2015 and that was panel six. Consequently, panel six was also the only panel displaying evidence of having been cleaned again more recently, with abrasion, anthropogenic cutting, loss of rock coating, and textural weakness continuing to score higher each year.

Repeat Photography

Many of the stability patterns and concerns identified by the RASI analysis are reflected in the repeat photography assessment, along with a few explanations for certain counter-intuitive RASI element scores. As discussed previously, repeat photography for this study only comprises of modern photographs and photo subjects vary from whole panels to individual motifs to give a wider representation of visual change at the site. To that end, not every panel was repeated and some only display images from 2015 and 2016, as a means to assess specific element recovery. In general, the repeat photography shows increased glyph clarity—which is the assumed intention of local intervention—along with significant changes in rock coatings and lithobiont activity. For example, the motifs on panel seven are considerably easier to see but textural changes may cause these petroglyphs to deteriorate at a faster rate than when they were more obscure (Figure 5.13). More in-depth analysis of the eight repeated images reveal connections with the site's RASI score patterns and new conservation and management challenges. Wider whole-panel images will be discussed first followed by the more detailed single-subject repeats. Fortunately, many of the panels with the most interesting/significant RASI scores were among the whole panels repeated—including the boulder housing panels two and three, panel four (from two different angles), panel nine, and panel six.

Separate from the primary boulder and displaying some of the only improved RASI scores post-cleaning, the repeated photographs of panels two and three highlight visual changes that may have impacted the panels' scoring (Figure 5.14). For example, the large pill of debris in the foreground of the 2015 and 2016 images may represent a problem for panel two but not three, which is situated on the upper-left side of the boulder beyond the reach of moving debris. Additionally, the uncharacteristically lighter color and deepening of the petroglyphs on panel two in the 2015 image compared to panel three and previous years validate the speculation that the panel had been scrubbed—initiating significant textural changes visibly impacting the panel's stability in the post-clean photo, especially around the lower-left motif where cleaning seems the most concentrated. The most significant visual change, however, is one common among the repeated photographs for the site: the development of a dark algal coating in the 2016 post-clean photographs (figure 5.15). The cause and impact of this coating is unknown and will require further examination.

This algal coating, along with other issues, is also seen in both angles of panel four—one of the largest and more heavily scrubbed panels at Mount Rich. When viewed from downstream, the aesthetical changes in panel four are quite stark (Figure 5.16). The pre-clean 2012 image displays the colorful array

Figure 5.13: Repeat photographs of the upper section of Mount Rich Panel 7 from 2012 to 2016. The most noticeable change is in panel color and the clarity of motifs. For example, the petroglyph resembling a bowing anthropomorph in the lower center of the images is very obscured in the 2012 photograph, clear in the 2015 image, and still clear, despite algal growth, in the 2016 image. 2012 and 2015 photographs by Casey Allen, 2016 image by author.

Figure 5.14: Repeat photographs of the small boulder containing Mount Rich Panels 2 and 3 from 2012 to 2016. Plant growth around the boulder and rock coatings are the most obvious changes among the images. All photographs by Casey Allen, except 2016 (by author).

of mosses, lichens, and plant growth covering the large panel—admittedly negatively impacting its overall panel stability—however nowhere near as much as the trauma exhibited in the next image. The 2015 photograph displays the raw stone scrubbed clean of all the rock coatings and lithobionts present in the previous image, as well as a large debris pile in the foreground of cleared vegetation from around the site. Closer inspection of the panel revealed deep scour marks from the speculated wire brushes used to clean the rock art. While the individual motifs are easier to see in the 2015 image, the impact of event was recognized in the elevated RASI scores and later in the 2016 post-clean image. Demonstrating casual local attitudes towards the stones, with the two boys climbing atop the boulder, the 2016 image shows the same development of a dark algal coating as panels two and three. While it has helped cover the raw stone exposed the year before, whether or not this is a beneficial or damaging rock coating is yet to be discovered. These patterns are just a clear when the panel is viewed more closely from the stream itself (Figure 5.17), with advancements in fissuresol development and potential detachment of the large scale in the center of the panel more apparent. The "fuzzy"-appearing granular destabilization of the so-called Sun God motif on panel nine is also visible on the right-hand side of the boulder.

Figure 5.15: macroscopic photograph of the algal coating found on most panels at Mount Rich. Further research is necessary to determine species or morphology of this coating. Its emergence and prolific proliferation aver the course of a single year is a significant landscape change that deserves additional attention in future examinations of the site. Photograph by author, 2016, shown in color for better identification of coatings.

Figure 5.16: Repeat photographs of Mount Rich Panel 4 from 2012 to 2016. Rock coatings and surrounding landscape display the most change. 2012 and 2015 photographs by Casey Allen, 2016 by author.

Figure 5.17: Repeat photographs of an alternate view of Mount Rich Panel 4 and part of Panel 9 from 2012 to 2016. Rock coatings and surface texture are the most visible differences over the last few years. 2012 and 2015 photographs by Casey Allen, 2016 by author.

Panel nine, with the most famous and well-known petroglyphs at Mount Rich, is one of the only panels visible from the road, so its repeat photographs were taken from this vantage point (Figure 5.18). When seen from above, contextual changes such as vegetation/debris removal as well as the boulders proximity to the stream are relatively obvious. The plant growing in a fissure on panel four in 2014 has been removed, as has the fallen tree from 2015. Small debris and leaves around the base of the boulder hint at the floods that frequent the St. Patrick River. In terms of panel nine specifically, located at the base of the large boulder, the scrubbing of the stones and removal of rock coatings seen in the 2015 image increase the motifs' clarity, albeit while simultaneously decreasing its stability. The 2016 post-clean image shows a more uneven algal coating than those found on the more vertical panels at the site. The streaky patterns of the coating may suggest rainfall or water run off has limited establishing more holistic coverage. Interestingly, however, an algal colony appears to have developed *within* the lines of the Sun God glyph—making it even more visible from a distance. Also visible from a distance is the aesthetical disintegration of the Sun God—decreasing detail sharpness and appearing "woolly" or generally less stable through the years. On the top end of the boulder, the stark white/grey of raw stone remains through the 2016 image, potentially clarifying the continuously increasing RASI scores for panel six, which is located near this section of the stone.

As the only panel to score higher in post-clean 2016 RASI than the peri-clean 2015, the repeat photography for panel six provides a possible explanation for this anomaly (Figure 5.19). Similar to panel four, the 2012 photograph highlights the colorful lithobionts that inhabited the stone's surface and the 2015 image shows the panel stripped of these coatings. Unlike panel four, the 2016 image does not

Figure 5.18: Repeat photographs of Mount Rich Panel 9 from the road, 2014 to 2016. Image quality is not as clear for these images, as at least one photograph was taken on a smart phone. Vegetation and rock coatings are among the most visible changes. 2014: Casey Allen, 2015 Cayla Kennedy, 2016: Author.

exhibit the growth of dark algal coatings witnessed throughout the site. The dark coating can be seen on the elaborate kite motif part of the much more stable panel five in the lower right corner of the images but not on the convex exposed pillow basalt of panel six in the center of the photographs. The starkness of the white panel six with its neighboring panels suggests this section of the stone may have been cleaned again more recently. Increased textural weaknesses and peculiar white areas outlining the panel's most intricate motif, as well as personal observation of casual local interactions with the boulder's surface, validate the speculation that continued interference with this section of the boulder, whether intentional cleaning or unintentional impact from children playing on the stone, is prohibiting panel six from recovering from the initial 2015 trauma.

To gain a better perspective of how scrubbing the stone has impacted individual petroglyph stability, two repeat pairs were taken of single motifs on two very differently scoring panels: panels five and nine. Panel five houses a deeply incised face motif that exhibits fairly significant changes, despite being one of the most stable panels at Mount Rich (Figure 5.20). The 2013 image displays the characteristic green moss that was common at the site, the face is barren in 2015 with fresh decay such

Figure 5.19: Repeat photographs of Mount Rich Panel 6 from 2012 to 2016. Panel 6 is unique as it is located on the only area of exposed pillow basalt on the main boulder. Coloration and glyph clarity are a few of the more obvious changes. 2012 and 2015 photographs by Casey Allen, 2016 by author.

Figure 5.20: Repeat photographs of the deeply incised face on Mount Rich Panel 5 from 2013 to 2016. Panel 5 was among one of the more heavily scrubbed panels, as seen in the 2015 image, and has since been mostly covered by the dark algal coating found one most panels in 2016. 2013 and 2015 photographs by Casey Allen, 2016 by author.

Figure 5.21: Close up repeat photographs of a scrubbed face on Mount Rich Panel 9 from 2015 and 2016. The scrub line running directly through the lichen colony on the left side of the images illustrates how the local volunteers paid special attention on the individual glyphs. Since the cleaning, new lichen and mosses appear to have inhabited some of the scrubbed surfaces within the petroglyph. Photographs by author.

as the chip in the lower lip, and in 2016 the face has been covered with the anomalous dark algae. Along with the algal coating, the face appears to have developed a surprising number of small white lichen colonies across much of its features and the stone surface directly to its right—which could cause substantial problems in the future.

Coming from a much less stable area, a motif assessed on panel nine was photographed more closely and provides hints as to how the local “conservators” approached cleaning the petroglyphs (Figure 5.21). Only showing images from 2015 and 2016, this repeat pair specifically focused on glyph recovery and the more minute impacts of the cleaning. The groove scratched through the white lichen patch in the center right of the image suggests the locals not only scrubbed the surface indiscriminately but also followed the lines of the motifs themselves. The small scour marks in the lichen and stone reflect the immense pressure and intensity at which these petroglyphs were cleaned. Unfortunate for this particular motif, the voids left by the cleaning have since been filled with soil and algae, as seen in the 2016 image, which, given the panel's horizontal orientation and myriad of shallow fissure, may dramatically increase its vulnerability to fissuresol development and further decay. The visual deterioration and increased textural anomalies also visible in the 2016 photography could be a consequence of the trauma incurred the year before.

5.4 – DISCUSSIONS AND CONCLUSIONS

Exhibiting some of the best examples of Amerindian rock art in the Lesser Antilles, both Duquesne Bay and Mount Rich have been subject to numerous conservation efforts—some more controversial than others. But were they effective? At Duquesne Bay, is the retaining wall built to prevent sand inundation actually protecting the petroglyphs or does the standing water trapped at its base cause more damage than the wall is worth? Despite the best of intentions, did the local site/stone cleaning at Mount Rich really help the site's stability or make it worse? The purpose of this study was to use rapid field assessment techniques repeated over five years to answer these questions by determining change in geologic stability and visible landscape change.

For the coastal Duquesne Bay rock art site, standing water has been the primary issue but with new efforts to provide drainage and potentially destabilizing slopes could shift concern to the third panel beyond the effects of the retaining wall. The average RASI scores for the primary boulder have remained relatively high but consistent—suggesting some element of site stability, which is highlighted in the repeat photography. Stagnant water is by far the biggest issue but the new Ministry of Tourism initiative to provide drainage could go a long way in decreasing the decay processes impacting panels one and two, while continuing to keep the boulder from being buried by beach sand. Unfortunately, the same cannot be said for panel three, when wider issues of slope instability and mass wasting are major threats. The rock art itself is fairly stabile but the boulder on which is it located is not. If the slope were to fail, the panel would most likely fall face down and the glyph would be lost. Preemptively repositioning the boulder or providing some form of support could decrease the chances of rock fall but this would be expensive and unlikely to gain local backing. Considering the panel's distance from the main boulder and general disregard by local caretakers, the significance of panel three in terms of tourism and revenue is considered by most to be minimal compared to panels one and two. This is an unfortunate mindset as the bi-faceted positioning of the petroglyph is unique among the island's rock art.

The overall effectiveness of conservation efforts at Mount Rich is slightly more complicated, as the local intervention was considerably more direct and invasive in its application. The community cleaning of the site seemed to have two separate agendas—to clear the area of vegetation and debris and to clean the stones themselves—each with different results. Panel three, the only panel to show improvement post-cleaning was only party to the first agenda, clearing debris, and was not cleaned directly. Panel two, located on the same boulder as panel three, was affected by both agendas and exhibited much higher degradation as a result. This may suggest that had the group only cleared surrounding vegetation and debris and *not* scrubbed the stones, their efforts may have been more beneficial to the site's overall stability. The main large boulder at the site, having experienced the most intense cleaning, displays some of the most detrimental consequences of the event. Panels such as panel nine, with the prominent Sun God with diminishing petroglyph clarity and granular stability, and panel six, still void of critical rock coatings, still exhibit the negative effects of the traumatic cleaning event. These are compounded by the introduction of the newly exposed raw surfaces to the elements and developing algal coating, whose long-term effects are yet to be determined.

All that said, the reality of Grenada's economic needs and natural/cultural resource limitations are also factors in the management of and interactions with the Island's rock art. The tourism industry dominates Grenada's economy (Martin, 2007) and the Carib Stones represent a significant un-tapped cultural resource, especially at Mount Rich where the local MAREP agency is already attempting to establish tourism revenue outlets. To that end, the local group responsible for cleaning the site may have been more concerned with making the site more visible from the road than increasing site stability. If this is the case, then their efforts were successful, if only in the short-term. The cleaning may have made the stones immediately more visible but by exposing the raw stone and increasing the surface's vulnerability to new algal colonies and decay processes, cleaning the stones may have decreased their longevity and long-term usefulness as cultural tourism resources into the future.

While five years may be a relatively short period of time to assess rock decay, Grenada's rock art landscapes are highly dynamic, and in the case of Duquesne Bay and Mount Rich, heavily impacted by human activity. The temporal flexibility of both RASI and repeat photography as field assessment techniques provided significant insight into the decay and landscape changes of Grenada's Carib Stones, requiring less than a week of field time each year, thus, allowing more time for analysis or immediate dissemination of the results to agencies most invested in prolonging the site's overall stability. The five-year window analyzed in this study not only reiterates concerns previously presented by Allen and Groom (2013a, 2013b), but also determined how decay factors have changed over time—identifying long-term potential threats, management effectiveness/faults, and future research needs.

CHAPTER SIX: CASE STUDY #3

From Rock Art to Edifices:

A Preliminary Adaptation of Pre-existing Field Techniques to Assess Cultural Stone Stability in Petra, Jordan

6.1 – INTRODUCTION

The ancient city of Petra, hidden in the colorful sandstone cliffs of southern Jordan, has become one of the Kingdom's most popular tourist destinations and attracts visitors from all over the globe—but at what cost? Similar to many other popular destinations, widespread tourism was not prevalent in Petra until post World War II, when international travel became more accessible to the average consumer. Nominated by the International Council on Monuments and Sites (ICOMOS) as an irreplaceable archaeological site, Petra gained the esteemed distinction "Cultural Heritage Site" in December of 1985, effectively turning the once lost Nabataean Capital and its gateway town of Wadi Musa into the country's most visited tourist attraction with nearly a million visitors in 2010 (PNT, 2013). Within less than a century, the city of Petra went from a forgotten desert refuge to a booming tourist destination witnessing hundreds of thousands of visitors each year. Understanding the effects of this radical transformation—both the risks and benefits—is imperative to the city's long-term survival. While some monuments have begun to deteriorate more intensely under the strain of continual tourist activity (Paradise, 2010), others have experienced revitalization and restoration due to boosts in the local economy and notoriety that comes with global tourism.

As with rock art, the management of cultural stone sites, such as Petra, can benefit significantly from rapid field assessment techniques of stone decay and landscape change. Knowing how and where change is occurring can lead to more informed and effective management policies. An example of this process in Petra is the UNESCO-initiated "Siq Stability Project" where researchers identify potentially dangerous sections of the Siq, Petra's main entrance, allowing engineers and geologists to preemptively remove loose material before it falls or causes mass wasting (see www.unesco.org for more). This project has been relatively successful but it only addresses one specific area. Similar work has been conducted in various parts of Petra (e.g. (Paolini et al., 2012), but more research is needed to truly understand the extent and cause of rock decay and landscape change throughout the ancient city. The other two case studies in this dissertation have illustrated how rapid field assessment techniques are efficient tools for providing cost effective and timely analyses of rock art stability—the same kind of analyses that could greatly benefit culturally and environmentally fragile places such as Petra. To that end, this chapter explores the merits of adapting existing rock art research methods to assess other forms of cultural stone via a preliminary analysis of monument stability in Petra, Jordan.

6.1.1 – Site Setting

Located in southeast Jordan, the ancient city of Petra lies in the mountainous region between the highlands of the Wadi Araba and the vast eastern desert. The now-vacant monuments along the cliff faces and valley floor represent a long occupational history fostered by the steep protective cliffs and unique environmental conditions (Groom, n.d.). Part of the Northern Araba Drainage Basin, Petra's complex physical landscape contains dramatic cliffs, slot canyons called siqs, and a myriad of wadis (ephemeral streams) that run through the city (Figure 6.1). Poetically titled "The Valley of the Crescent Moon", the main valley of Petra resembles a crescent moon when seen from above. With an elevation ranging 900-1000m, the city exists within the transitional zone between the temperate Highlands and the arid Wadi Araba. While Petra's climate is technically a Mid-Latitude Dry Semiarid Steppe (BSk in the Köppen Classification), its cool, wet winters and hot, dry summers are more characteristic of a Mediterranean-type climate (Cordova, 2007). In the valley, average winter temperatures range from 6˚-12˚C with 15˚-32˚C in the summer with less than 130 mm average annual precipitation (Jordanian Meteorological Division, 1971). Collection of current long-term meteorological data has been limited due to complications ranging from theft of equipment to lack of sufficient funding. Petra's physical features and rainy winter climate make the valley prone to flash floods—the main valley, Wadi Musa, can be very dangerous during storms, especially in the narrow entrance at the Bab As-Siq (Al-Weshah & El-Khoury, 1999).

The relative abundance of wadis, along with strategic water management systems, has supported life in Petra for thousands of years—both flora and fauna. According to a biodiversity survey conducted in

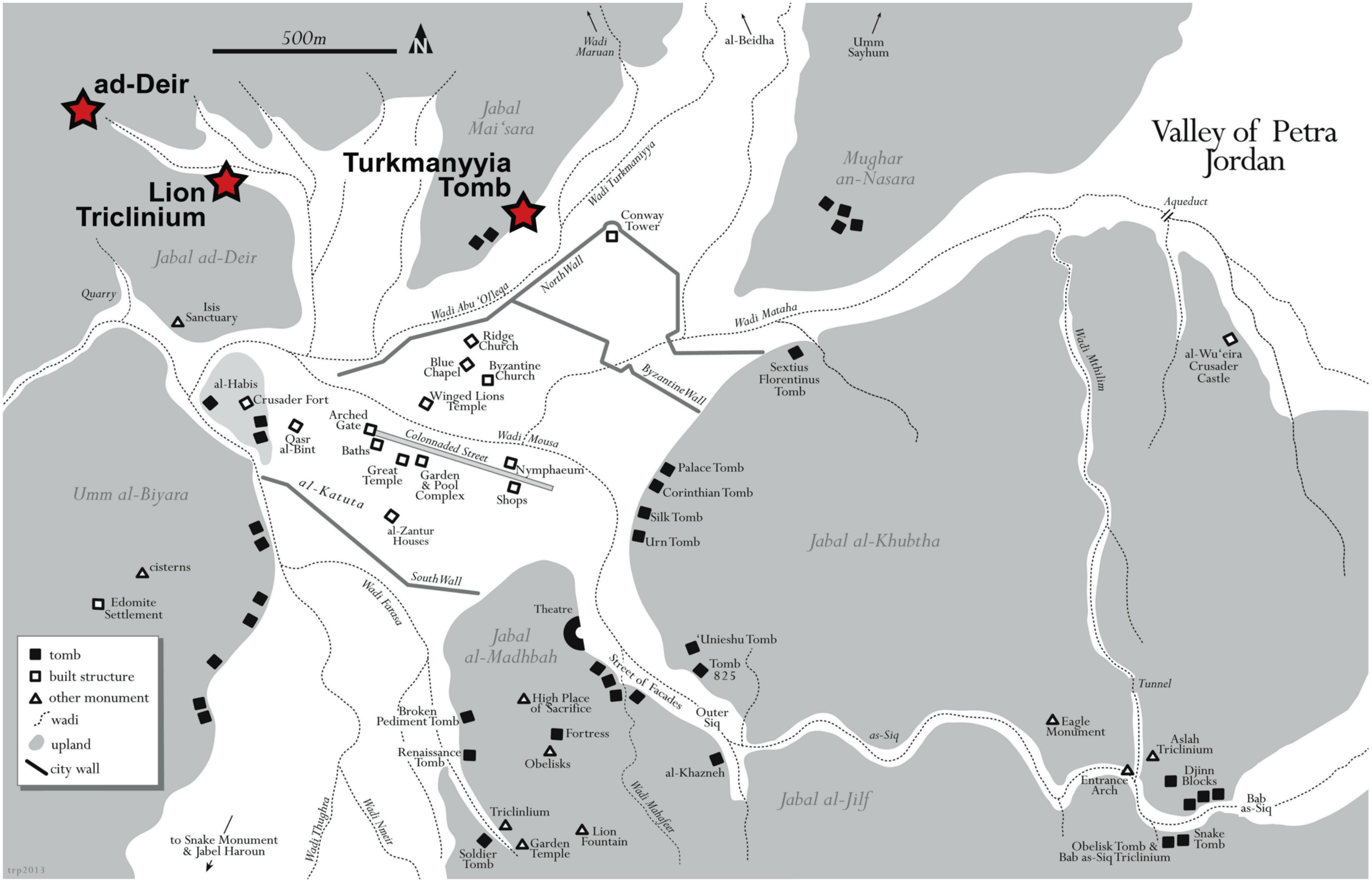


Figure 6.1: Aerial map of the Petra Valley with the three assessed monuments highlighted in red. Cartography by T.R. Paradise from J. Taylor (2001).

the mid-1990s, over 700 different plant species and nearly 400 animal species reside in the valley (Ruben & Disi, 2006). Flora in the valley mostly consists of *Anabasis* shrubs and *ziziphus lotus* with a spattering of *Haloxylon articulatum* and *Salsola villosa* in the saline wadi bottoms (Cordova, 2007). There are patches of greater hardwoods, such as Oaks, found around the area, although these are becoming less common. Native fauna in the valley, besides humans, mainly include various species of reptiles and birds. Most reptiles in Petra are snakes and lizards, such as several species of Fringe-Toed Lizards (*Acanthodactylus* Genus) and Dwarf Racer snakes (*Eirenis* Genus)(Maani, 2010). Petra's bird population, including both permanent residents and migratory species, range from birds of prey, such as European Scops-Owls (*Optus scops*) and Long-Legged Buzzards (*Buteo rufinus)*, to small songbirds, such as Rock Martins *(Ptyonoprogne fuligula*) and the Blue Rock-Thrush (*Monticola solitaries*)(Maani, 2010).

However, Petra's most iconic and prominent physical feature is its vibrant sandstone. Accommodating the city's ancient architecture and embedded monuments, the valley's unique geology offers a mesmerizing display of color and texture. The contrasting red and white sandstones, liesegang banding, iron veins and nodules, and rich desert rock coatings have inspired countless poetic monikers for Petra such as "The Rose-Red City" (Burgon, 1845). Exhibiting some of the oldest exposed sandstone on earth, Petra's geology is comprised of two siliciclastic sections of the Ram Group: The Cambrian Umm Ishrin Sandstone and the younger Ordovician Disi Sandstone. The Umm Ishrin Formation is a quartz arenite with cross-bedded components of siltstone and mudstone, feasibly representing the fringe of a fluvial system (Abed & Khaled, 1983). The Umm Ishrin is also the source of the famous "Rose Red" color found throughout the city, although it also exhibits other colors including salmon, chocolate brown, and deep mustard yellow. Alternately, the distinctively white or cream Disi Formation composes much of the city's higher elevations and cap rock. Much courser in texture, the Disi Sandstone lacks horizontal cross bedding and was most likely deposited in a braided stream environment among dunes and sandbars (Alsharhan & Nairn, 1997). While the Disi formation is relatively uniform across much of Jordan, it is more inconsistent in Petra due to irregular contact and large amounts of interdigitation with the as-Shara Limestone on the northeastern edge of the valley near the Bedouin village, Umm Sayhoun (Bernd Fitzner & Heinrichs, 1998).

Since Petra's famous cultural components are, literally, embedded in their natural environment, both physical *and* cultural elements of the city can influence cultural stone decay and landscape change. Therefore, it is necessary to not only address the physical landscape but the archaeological site's historical and cultural context as well. Often called The Lost Kingdom of the Nabataeans, the Nabataeans were the earliest documented civilization to occupy Petra, beginning around 580 BC (Browning, 1973). The Nabataean people are credited with creating some of the most recognizable and inventive features in the city, such as the monolithic tombs of al-Khazheh (the Treasury) and ad-Deir (the Monastery) along with the intricate water retention system. Promising water and protection to caravans and traders traversing the brutal Arabian Desert, the city quickly became a thriving central hub in the region. Much like modern international cities, various cultures and ethnicities became integrated into the landscape, evident in the city's eclectic architecture and artifacts displaying Hellenistic, Roman, Assyrian, and Egyptian influences (Tholbecq, 2007). The city's success made it powerful and Nabataean Kingdom wasn't annexed by the Roman Empire until 106 AD, well into the height of Roman expansion (Fiema, 2003). Renamed "Arabia Petrea", the city was given typical Roman features, such as gardens and grand water features, along with the infrastructure necessary to sustain nearly 30,000 people (Fiema, 2003).

After major trade routes shifted to other Roman cities, such as Jerash and Palmyra, and the development of sea trade around the Arabian Peninsula, Petra's prosperity came to an end. Following gradual economic downfall, Petra was devastated by massive earthquake in 363 AD (Russell, 1980), possibly followed by catastrophic flooding (Paradise, 2012). Byzantine structures and architectural influences suggest at least some degree of human activity in the following centuries, but it is unclear how many people resided in the valley during this time (Fiema et al., 2001). Strategically located, Petra's Crusader occupation in early 1100s AD was limited to a few military outposts, such as the small mountain fort Al-Habis in the main valley and the larger fortress of Al-Wu'aira on the other side of al-Khubthuh mountain (Hammond, 1970). After the Crusader Kingdom dissolved in 1191 AD, Petra fell into obscurity, lost to the western world until Swiss explorer Johann Ludwig Burckhardt (1784 – 1817) "rediscovered" the city in 1812 (Browning, 1973).

While it is often coined a "lost city", many would argue Petra was never completely deserted. Generations of semi-nomadic Bedouins lived among in the ruins, especially members of the Bedul tribe, making use of the caves and water retention systems. Primarily camel and goat herders, the Bedouins typically resided in large portable tents but the stone sanctuary of Petra was a convenient refuge. However, since the site's 1985 induction in the World Heritage program and exponential tourism growth, Bedouins are no longer permitted to live in the valley and the vast majority of the Bedul Bedouins were involuntarily relocated to the government-built village of Umm Seyhoun outside of the archaeological park (Shoup, 1985). While later installments of roads leading back to Petra allow Beduls a livelihood in the tourism sector, contention remains and the complicated relationship between the locals and the government agencies responsible for their expulsion present a number of heritage management and conservation challenges.

6.1.2 – Existing Rock Decay Research in Petra

The majesty of Petra, and the unique management challenges it poses, has drawn the attention of several academic and scientific research communities—though the vast majority of research in Petra has been archaeological. In fact, Petra's scientific history has been dominated by intensive archaeological endeavors, such as the famous 1897-1898 Brünnow and von Domaszewski survey of the Arabian Province during which nearly every monument in Petra was documented and numbered, designations still in use today (Brünnow et al., 1905), and the massive 1993-1997 exhumation of the Great Temple in the city's central valley (Joukowsky, 1998). More recently, areas of the ancient city still being cleared, excavated, and exposed to the thousands of visitors each year include the so-called "Royal Necropolis" on west side of al-Khubthah mountain (Wadeson, 2014) and the Petra Garden and Pool Complex adjacent to the Great Temple (Ramsay & Bedal, 2015).

That said, some archaeologists have recognized the complicated management issues threatening Petra and have focused their work on promoting more sustainable research and conservation methods. For example, in 2009, the lead scholars for the ongoing excavation of the Temple of the Winged Lions, sponsored by the American Center of Oriental Research (ACOR), pioneered the Temple of the Winged Lions Cultural Resource Management Initiative (TWL-CRMI). In junction with ACOR, the Jordanian Department of Antiquities, and the Petra National Trust, the initiative aims to regulate conservation techniques, improve and uphold educational standards for local management personnel, and compile a comprehensive report of monument conditions and stability (Tuttle, 2013). The very need for such an initiative highlights the some-what chaotic nature of stone conservation efforts in Petra, despite the establishment of the Conservation and Restoration Center in Petra (CARCIP) in 2002.

There have been several preservation-focused studies conducted in Petra, but these are usually limited to disjointed preliminary monument-specific case studies, as many of the techniques employed were either prohibitively expensive or experimental. The focus of these studies have included exploratory pre-intervention examination of structural integrity and building materials (Bani-Hani & Barakat, 2006), laboratory analyses to identify the most appropriate mortar for the reconstruction and restoration of Petra's built monuments (Al-Saad & Abdel-Halim, 2001), multispectral photography and 3D recording for systematic documentation of decay (Haddad et al., 2015) and experimental applications of different conservation techniques on isolated tomb facades to test their effectiveness (Aslan & Shaer, 1996; Wedekind & Ruedrich, 2006). While most of these publications are goal-oriented and focus on the effectiveness of various conservation, restoration, and/or preservation methods and techniques, few address naturally occurring geomorphologic and rock decay processes directly.

Alternatively, Petra's unique stone landforms and geologic anomalies have also attracted academic scholars more science-focused without clear heritage conservation intentions. These studies have included geomorphologic research categorizing rock-fall hazards in the steeper cliffs (Delmonaco et al., 2013), identifying evidence of past catastrophic flood and earthquake events initiating massive landscape changes (Paradise, 2012; Russell, 1980), and investigating sandstone decay thresholds and tafoni development throughout the city (Gomez-Heras et al., 2012; Heinrichs, 2008; Paradise, 1995, 2013). Although historic preservation and heritage management entities could benefit significantly from empirical geomorphologic research such as these, there is surprisingly little discussion between the conservation practitioners and scholarly researchers in Petra—theoretically limiting what each side can accomplish (Smith et al., 2008).

That said, there have been a few scholars that have been able to bridge the gap between rock decay science and heritage/tourism management. In a time and resource intensive study, Bernd Fitzner and Heinrichs (1998) conducted numerous laboratory and in-situ field investigations to identify weathering (rock decay) profiles and decay rates, petrographic characteristics and weaknesses, as well as structural

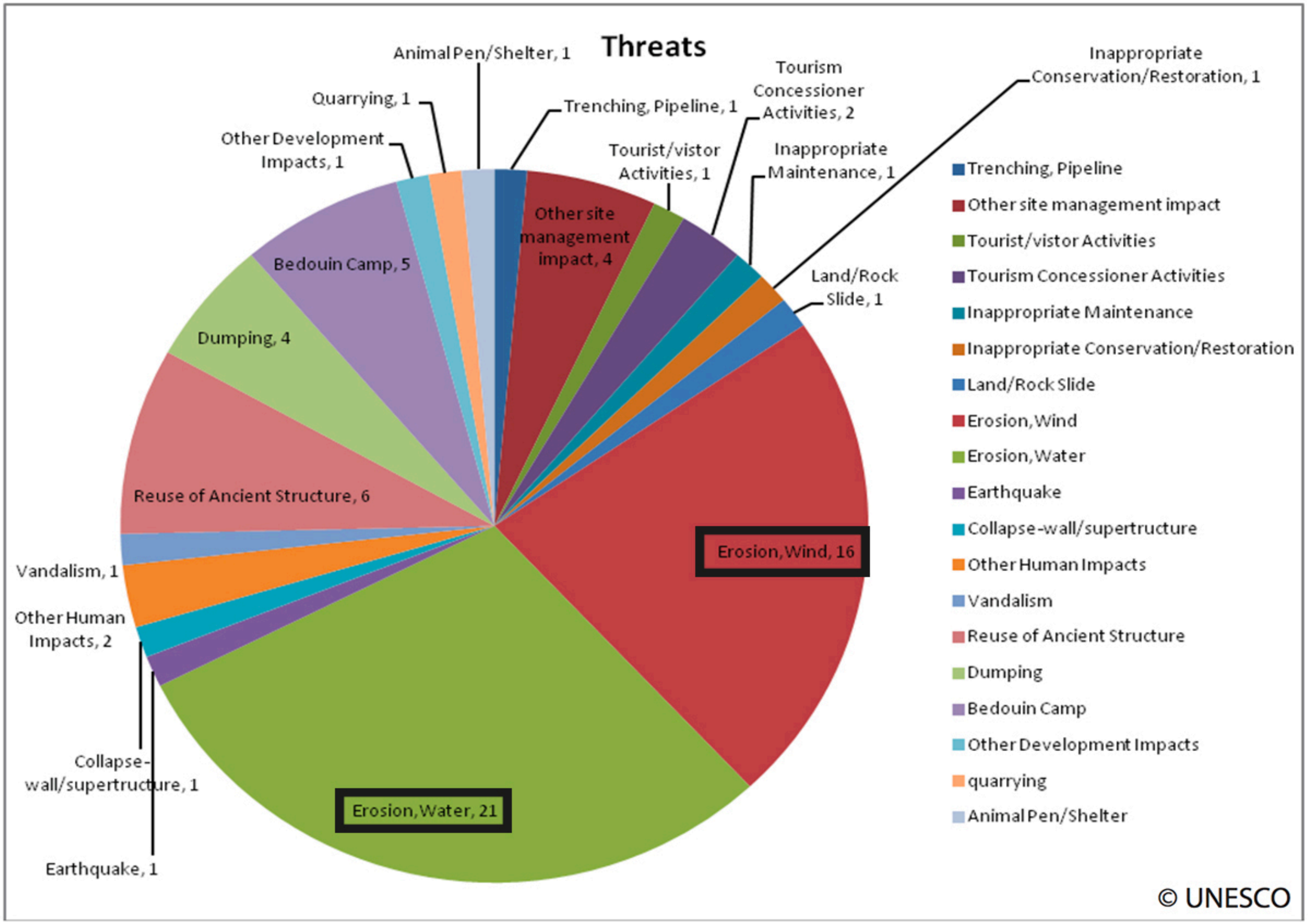


Figure 6.2: Graphic from Paolini et al. (2012) displaying different identified threats to the Monetary Trail in Petra. The two largest wedges are dangerous over-simplified when compared to the details of the other assessed threats.

factors such as porosity, pore-size distribution, water absorption and evaporation rates, etc., with the explicit intention of determining the most promising conservation techniques. While the scientific merits of this work are remarkable, the practicality of such an in-depth investigation for management purposes is questionable, especially for a site as large as Petra. Attempting the establish more timely research techniques, a UNESCO-lead research team recently conducted a preliminary rapid risk assessment meant to identify both natural and anthropogenic threats to Petra's landscapes (Paolini et al., 2012). Working with representatives from the Jordanian Department of Antiquities, the Raymond Lemaire International Center for Conservation (RLICC) at the Katholieke Universiteit Leuven in Belgium, the Getty Conservation Institute (GCI), and the Petra Development and Tourism Regional Authority (PDTRA), the results of the study were impressively detailed considering their limited time in the field. However, despite having experts from archaeology, geology, and engineering, the geophysical and rock decay components of the study were dangerously over-simplified, almost to the point of being counter-productive (Figure 6.2), only serving to further exemplify the debilitating disconnect between conservationists and geoscientists.

A possible solution to this conundrum may be a matter of adaptation. Instead of recreating new disparate methods and avenues of exploration between management and science, perhaps scholars need to focus on adapting components of pre-existing conservation practices with geomorphologic techniques to create more holistic research accessible from both sides. This chapter attempts to do just that. Analyzing the same monuments as the Paolini et al. (2012) UNESCO risk management assessment, the Dier, the Lion Triclinium, and the Turkmanyyia Tomb, this case study illustrates how adapted existing research methods and rapid field assessment techniques can benefit heritage management in scientifically disconnected places such as Petra, Jordan.

6.2 – CASE-SPECIFIC METHODS

As a case study to assess both monument geologic stability, rock decay, and overall landscape change in Petra, elements lacking in the UNESCO study, all three monuments were assessed using an adapted version of the Rock Art Stability Index (RASI) called the Cultural Stone Stability Index (CSSI) along with repeat photography. While more in-depth descriptions of both RASI and repeat photography can be found in Chapters 3.2 and 3.3, respectively, this subchapter outlines specific details pertaining to this case study, such as RASI's conversion into CSSI and the source of historic photographs for repetition.

6.2.1 – Cultural Stone Stability Index

In most situations, rock decay is ubiquitous. All stones decay, regardless of geologic material, function, or content. The same major geomorphologic processes that damage rock art panels also threaten all other forms of natural and cultural stone. Therefore, with only a few terminological changes, the core index that composes RASI can be adapted to address a broader research topic of cultural stone. Termed the Cultural Stone Stability Index (CSSI), this modified index can be used to assess anything from building facades and statues to bridges and gravestones. The CSSI functions in the same manner as RASI. Practitioners define and sketch the target feature (or panel for RASI), and then rate each rock decay process on the same scale of 0-3 divided into the same six categories, ending with a doubled final score indicating the feature's geologic stability. In fact, the indices are so similar that RASI has been used to assess built monuments well before the conception of CSSI (Groom, 2011).

Within the index itself, only a few changes are needed to transform RASI into CSSI (See Appendix G for a visual comparison). These changes are usually terminological and not related to different rock decay processes—simply broadening the scope from specifically rock art to encompass more general cultural stone subjects. For example, the RASI item "rounding of petroglyph edges" is changed to "rounding and/or blurring of carved edges or inscriptions"—both elements rate loss of detail, just in different terms. Although, there are a few elements added specifically for buildings and cultural stone decay completely unrelated to rock art, such as "anthropogenic fissures" in the Site Setting and "anthropogenic joints/jointing" in Incremental Losses, both focusing on decay processes involving mortar work.

The section that requires the most modification is Rock Coatings, due to the different roles of rock coatings between rock art and other cultural stone (Dorn, 1998). For certain types of rock art, many rock coatings are not only beneficial, but also necessary for their existence. Most petroglyphs, for example, are created by pecking or scraping through rock coatings to reveal the raw stone beneath the surface (Whitley, 2005). The contrast between the coated exterior and newly-exposed interior makes the art possible. Therefore, in RASI, two of the four rock coating elements have negative scores—indicating them as stabilizing agents. Alternatively, stone building facades and most other cultural stone are created with freshly quarried material, so any rock coating accumulation takes place after the stones are already in situ and beginning to decay. Also, since historic buildings and cultural stone often exist within cities and populated areas, as compared to the relative isolation of rock art sites, they may experience higher exposure to air pollution and urban traffic exhaust, leading to the development of harmful toxic rock coatings (Smith et al., 2005). To accommodate this difference, the CSSI adds two more elements to the Rock Coating section: "carbonate coating" and "oxidation", each with positive scores reflecting their destabilizing influence. The two Rock Coating elements with negative scores in RASI ("case hardening" and "rock coated present") still have negative scores in CSSI, but with CSSI the specific coatings associated with pollution and enhanced urban decay (carbonates and oxidation) can be individually evaluated and added to the total score.

While CSSI shares most of RASI's strengths and weaknesses as a research tool (see Chapter 3.2.1 for review), there are a few new challenges and benefits that come with CSSI specifically. For example, Unlike RASI, CSSI compares current conditional statuses against assumed non-decayed baselines, since most cultural stone resources were created from "new" material. With RASI, researchers need to recognize that there will be a certain degree of "inherited decay"—rock decay that took place before the rock art was created—in their final scores since most rock art exists on pre-exposed surfaces. In contrast, the "virgin surfaces" of built monuments and building facades foster the assumption that all decay present has occurred after the completion of the resource. This assumption provides researchers with a controlled timeline of decay—allowing them to estimate factors such as rates of decay and date of decay initiation, which are much more difficult to calculate in natural settings. That said, the possibility remains that assumed baselines can skew results if the original surface was different than presumed (e.g. if stone dressings imitating textural deterioration were applied intentionally). In surveyed sites, such as Petra, baselines could be structured after archaeological records or sketches created by early scholars in the region (e.g. Figure 6.3).

Another practical difference between RASI and CSSI is one of panel/feature definition. When preparing a rock art site for RASI analysis, individual panels are usually fairly easy to distinguish and are often already identified via archaeological surveys or site records (e.g. Groom & Poole, 2010; Groom & Thompson, 2011). Rock art panels usually consist of relatively flat and uniform surfaces, such as cliffs or sides of boulders, so division can be based simply on panel aspect or concentration of motifs (e.g. Groom, 2016c). When dealing with large building façades, statues, or other more detailed cultural stone, site mapping and preparation can be a little more complicated, but also more flexible. CSSI researchers have the ability to define panels/features in whatever way best suits allotted field time, available resources, or desired precision. For example, a square building could be divided into four panels by aspect (i.e. “north side”, “east side”, “south side”, “west side”) or the same building could be divided by feature (e.g. “north side window arch 1”, “north side window arch 2”, etc.). That same building could be assessed by aspect first, and then any specific characteristics of particular interest or importance can be analyzed individually. A large building façade could be just as easily divided into a handful of quadrants or dozens of individual elements, depending on the design and intention of the research. While studies with more panels will provide a more detailed analysis, they are much more time intensive and risk becoming counter-productive. The intention of techniques like RASI and CSSI are to provide cost-effective rapid field assessments. If a building were divided into too many elements, a CSSI investigation would be prohibitively slow and potentially defeat the purpose of the work.

In Petra, to best utilize the benefits of CSSI while remaining within its limitations, this case study only includes three monuments, each divided into 8-18 panels each, despite massive differences in monument size and detail. The largest of the monuments, ad-Deir (or the Monastery), could have easily been divided into hundreds of panels but for the sake of time and detail necessity, it was divided into 18 panels based on prominent feature areas and architectural division. The assessment also included two panels on either side of the monument to provide context. The next largest monument, the Turkmanyyia Tomb, actually has the smallest number of panels (only 8 panels) due to the relative simplicity of façade décor and hewn features. However, the Turkmanyyia Tomb is significant in Petra in that it displays one of the world’s largest Nabataean inscriptions along its mantel. Therefore, after the monument was divided into 6 main panels, including contextual panels on either side of the monument, two more panels were designated to specifically address the area with Nabataean writing: one incorporating surrounding features and one dedicated only to the area with the inscriptions. This kind of flexibility within panel

Figure 6.3: Conceptual sketches of the three assessed monuments from Brünnow et al. (1905)—one of the first extensive surveys/publications addressing Petra.

definition in unique to CSSI, as it allows researchers to put an emphasis on key features of whatever cultural stone is being assessed. The third and smallest monument, the Lion Triclinium, was separated into 12 panels, including 2 contextual panels and a small icon niche to the left of the main monument. Similar to the Turkmanyyia Tomb, the Lion Triclinium was divided by general features but then additional panels were dedicated to specific elements unique to the monument: two carved lions on either side of the tomb entrance and two intricately carved faces in the monument's pediment, all assessed individually.

Although CSSI has been in development for years, this is the first time is has been employed as part of a stand-alone research agenda, as opposed to the unpublished academic pedagogical purposes for which it was created. Three researchers, each trained in both RASI and CSSI, evaluated every panel/feature for all three monuments, resulting in 114 total CSSI scores. Each panel's three scores were analyzed to provide a mean score, representing the assessment of all three researchers in one final score. These final scores were also averaged per site to calculate an over-all monument stability score, useful for quick comparisons between sites. Major concerns CSSI identified for both individual panels and sites in general were further investigated temporally using supplemental repeat photography at all three monuments.

6.2.2 – Repeat Photography

Repeat photography is a powerful rapid field assessment technique for quickly identifying landscape change over time (See Chapter 3.4 for more details), making it an ideal supplemental tool to assess Petra's monuments and their surroundings. Just as all stones decay, all landscapes change, it's just a matter of how and why. In Petra, each occupational period in its history left characteristic marks on the landscape: Nabataeans created iconic hewn monuments, such as the Khazneh and the Royal Tombs; the Romans left behind opulent pools, gardens, and temples; the Byzantines converted tombs to churches and marked the landscape with their distinctive mosaics; the Crusaders built forts borrowing stone blocks from previous civilizations' ruins; even the semi-nomadic Bedouins changed the landscape by occupying caves and grazing livestock throughout the city (Taylor, 2001). It, then, stands to reason that the current occupation of Petra, its "touristic occupation", is also influencing Petra's ever-changing landscape. Monument reconstruction and restoration with modern building materials are just a few examples of this influence (Fig 6.4).

In order to examine the impact of tourism on Petra's landscapes, as well as provide temporal control to CSSI stability analyses, this case study compared current landscapes with historic photographs pre-dating modern tourism in Petra. In 1925, long before international leisure travel was accessible to the average consumer, Sir Alexander B.W. Kennedy published a book titled: "Petra: Its History and Monuments". Contained within this volume are more than 200 high quality photographs of Petra's landscapes, monuments, and archaeological artifacts. The landscapes depicted in these photographs,

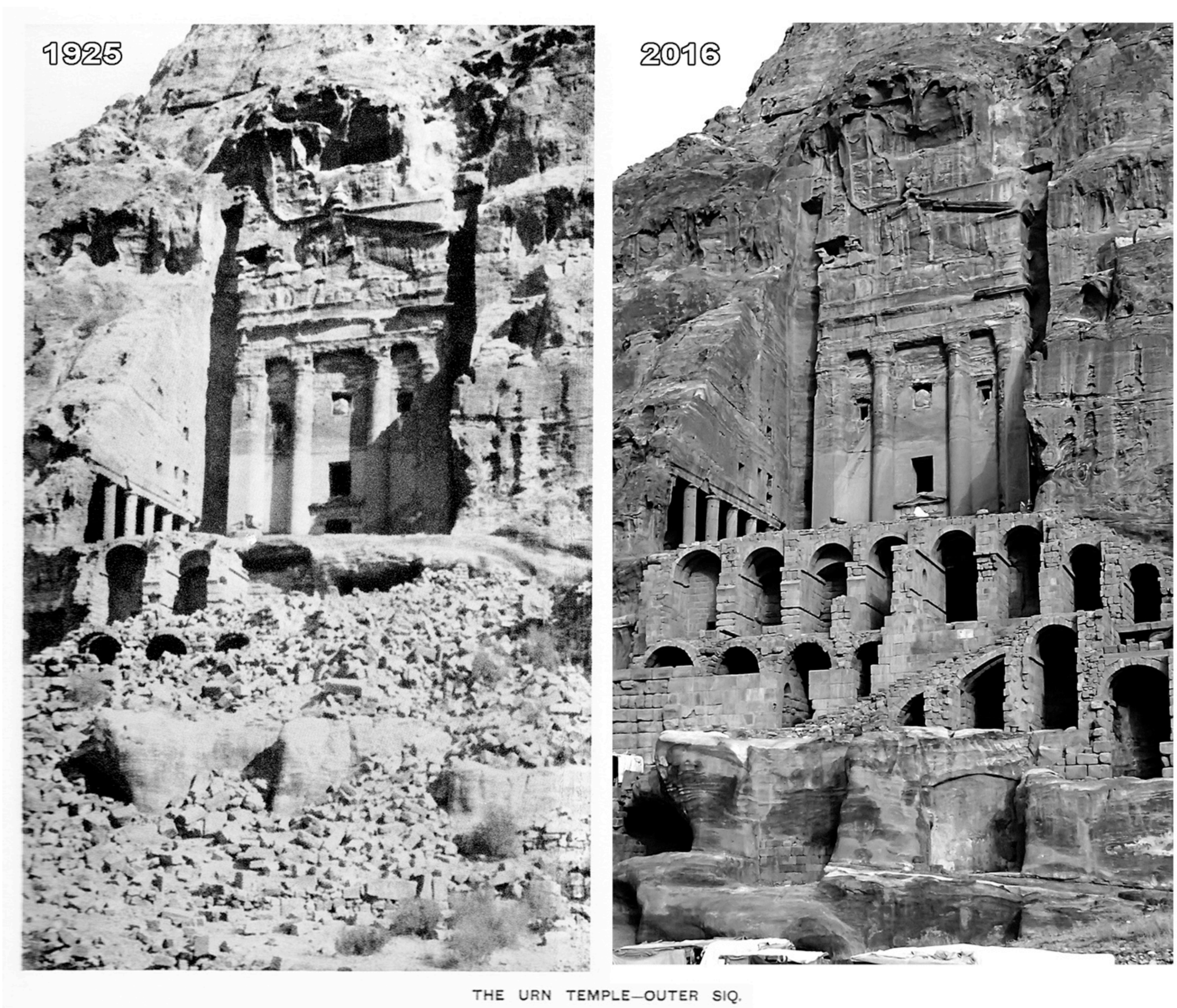


Figure 6.4: Repeat photographs of the Urn Tomb, one of the Royal Tombs. The reconstruction of the stairs and arches with modern materials are among the most notable changes. 1925 photograph from A. B. W. Kennedy (1925). 2016 photograph by author.

taken nearly a century ago, are raw and practically devoid of tourism, providing an excellent base line for modern comparison—and the differences can be rather stark. While there is immense potential for other tourism research involving Kennedy's 1925 volume, this case study only repeated three photographs: one of each of the three monuments. These repeat pairs were analyzed alongside the CSSI assessments to provide a more holistic rapid field assessment of both monument stability and contextual landscape change over the last century.

6.3 – RESULTS AND ANALYSIS

Including both CSSI scores and repeat photography pairs, the results of this case study are organized by monument: ad-Deir, the Turkmanyyia Tomb, and the Lion Triclinium. Individual scores, site averages, and major management/decay concerns are identified and discussed. Further exploration of method efficacy and significances, as well as site-to-site comparisons and future avenues of research, takes place in the subsequent sub-chapter.

6.3.1 – ad-Deir (The Monastery)

Located high in the western cliffs of Petra, the Deir (or *ad-Deir,* meaning "the Monastery" in Arabic) is among Petra's most impressive and iconic monuments. Measuring roughly 50m X 45m (165ft X 148ft), the massive double-story façade is one of the largest monuments in Petra and is thought be have been carved in the third century AD, though a number of chiseled crosses on the interior walls suggest it was adapted for Christian purposes several centuries later—thus the designation "Monastery" (Harding, 1990). Heavily influenced by the popular Hellenistic and Classical styles while also maintaining certain distinctive native elements, the Deir is an amalgamation of disparate architectural features characteristic of the Nabataean style (Browning, 1973). With its monolithic pilasters and quintessential split-cornice with subtle crow step decoration, as well as the absence of porticos or overly-intricate ornamentations, some scholars have praised the Deir as representing the height of Nabataean architecture and artisanship (Browning, 1973; Harding, 1990). Browning (1973) describes the design of the Deir as "Hellenism has been brought to heel and made to serve the Nabataean tradition" (p. 97).

Sitting at a higher elevation than the other two assessed monuments, the Deir is hewn from the picturesque golden-white Disi Sandstone formation. The general friability and vulnerability of the Disi formation is exemplified by the myriad of tafoni, sandstone drapery, and other advanced rock decay features on the cliffs surrounding the monument. Decay is also present on the Deir itself, though the sheer size of the façade gives it a deceptively stable appearance. To best evaluate the monument, the Deir was divided into 18 CSSI panels, including four contextual panels—dressed surfaces on either side of the formal monument itself. Because this particular façade is so large, each "panel" was several meters across and included multiple design features that might have benefited from more focused examination. That said, the purpose of rapid field assessments is to gain a quick "snap-shot" of general decay in order to quickly identify problems or areas that require more detailed analysis in the future. Prematurely separating the Deir into smaller sections would have been prohibitively time-intensive and counter-productive to the intention of the study.

CSSI

With an average CSSI site score of 59.09, the Deir rests precariously between the second highest and highest descriptive categories for RASI/CSSI—*Great Danger of Erosion* and *Severe Danger of Erosion*, respectively—indicating significant issues with this massive monument (Figure 6.5). Seemly stable when viewed from a distance, the grandeur of this façade serves to mask the myriad of decay processes negatively impacting the stone. In fact, binoculars were required to assess the upper levels, since the size of the monument limited access and viewing necessary to accurately identify decay features, many of which were indistinguishable with the naked eye from the ground. Upon closer inspection through binoculars, the Deir's many stability concerns are much more apparent.

These issues are reflected in the site's CSSI scores, with stone texture and corresponding factors causing the most concern. Incorporated in nearly every category of RASI/CSSI, texture is a physical characteristic of stone reflecting intrinsic lithological features, such as clast/matrix ratios, and can influence decay. For example, Paradise (1995) discovered several thresholds where sandstone matrix compositions, closely related to texture, strongly influenced decay rates. Arguably, rougher textures, manifestations of stone porosity characteristics, may suggest the stone is either more susceptible to or

Figure 6.5: The different CSSI panels and scores for the Deir. Colors coordinate with degree of degradation, ranging from green indicating stable conditions to yellow, to orange, to light red, to dark red signifying the highest CSSI scores and most significant decay. Graphic and photograph by author, 2016.

already experiencing decay processes that involve a deterioration of the matrices responsible for holding clasts together, such as flaking (both preparing and detached), granular disintegration, and scaling (McKinley & Warke, 2007; Přikryl & Smith, 2007)—all of which regularly scored high at the Deir. Changes or discrepancies in texture can also affect decay, such as iron banding creating impermeable layers within the stone stopping the movement of water, salts, and dissolved minerals between substrates. This can cause a build up of usually mobile elements, effectively localizing decay along specific textural boundaries (Warke et al., 2006). This is the case for the Deir, as bountiful iron concretions and leisegang banding throughout the monument have channeled decay along specific strata.

Textural anomalies have also created a spatial pattern of decay for the Deir, with the lower levels experiencing relatively higher rates of decay than the upper levels. Decay features commonly associated with salt accumulation, such as flaking and granular disintegration, ranked higher along the ground level

Figure 6.6: Closer photograph of the textural anomalies on the Deir Panel 12. Much of the horizontal striations and red coloration are exposed areas of the host sandstone where the stone dressing has deteriorated. The green patches are small bushes (roughly 0.5 meters diameter) for scale reference. Some graffiti and vandalism can be found on the lower sections of both columns. Photograph by author, 2016.

panels than the upper story panels with noticeably different surface textures between levels. This is most likely due to a large iron band dissecting the lower level of the monument, creating a distinctive stopping point for wicking salts and minerals migrating up the stone. The highest scoring panel at the site, panel 12: 80.0, contains the largest section of exposed sandstone below this boundary, exhibiting the immense damage that can be caused by concentrated salts and other expansive minerals (Figure 6.6). Additionally, anthropogenic textures may also seem to influence decay, as the panels with fewer carved details, such as the inset panels 4,6,8, and 10, as well as the contextual hewn walls on either side, earned much lower scores than the more intricate protruding edifices, though this could be due to other factors such as differences in environmental/insolation exposure or visibility limitations during analysis.

Repeat Photography

Providing a more aesthetical assessment of the Deir's contextual setting and physical condition, the repeat photography analysis identified a few major landscape changes over the past century that could influence the monuments stability moving into the future (Figure 6.7). The most obvious change has been vegetative. The shrub growing on the upper façade has been removed and the thick vegetation growing around the base of monument has been reduced to scattered grasses. The ground change in ground cover could be due to a number of factors including grazing, increased foot traffic, climate change, or intentional removal to enhance visual appeal or access to the site. Another explanation for the vegetation loss may be minimal excavation of the hewn niche in the left hand side of the image, as evident by a lower ground levels in the area and newly exposed soil lines and horizontal fissure in the recent repeat. In addition, the trees growing to the right of both pictures, subsequently obscuring part of the façade, are different species, indicating the previous tree either died or was removed and the current tree has grown in its absence.

In terms of the monument itself, the repeat pair illustrates the deceptively intact appearance of the monument by revealing relatively little discernable difference over the past century. Major decay concerns identified in the CSSI analyses appear to have been influencing the monument long before modern tourism was established in the valley. The large textural band influencing CSSI scores on the lower levels of the monument is clearly visible in the historic image, along with the advanced decay in the areas below it. The most significant structural difference between the photographs is the large hole in the center upper window. Closer inspection revealed what appear to be several bullet holes around the intentionally removed material, indicating vandalism as the cause for the discrepancy (Figure 6.8).

Unfortunately, vandalism and unsafe behavior is an on-going problem in Petra and at the Deir, forcing authorities to erect fences, signs, and walls denying access to fragile and potentially dangerous areas. The newly established guardrail preventing people from entering the inner chamber of the Deir is clearly visible along the base of the entrance, as well as the various signs informing visitors that going

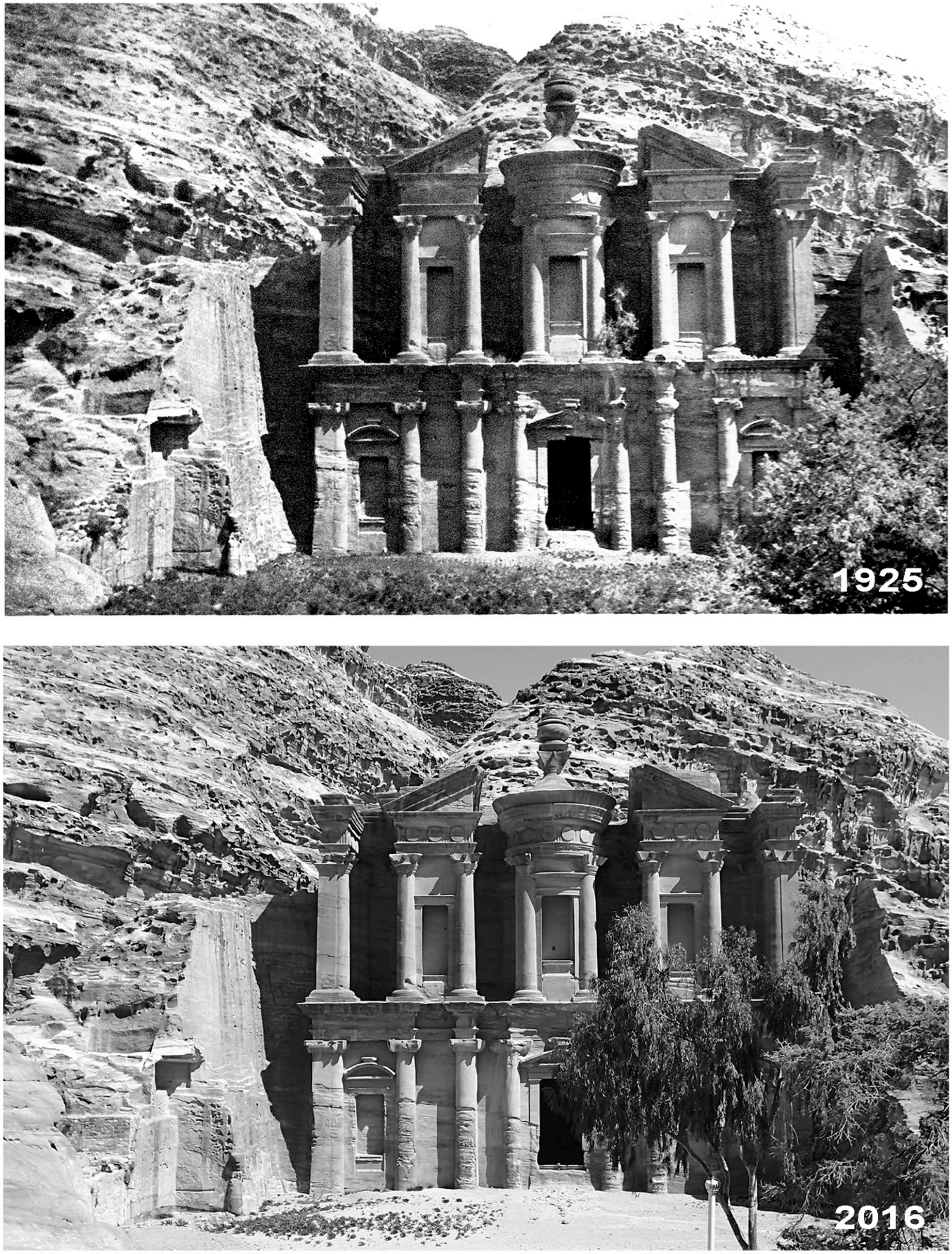


Figure 6.7: Repeat photographs of the Deir (The Monastery). 1925 photograph from A. B. W. Kennedy (1925). 2016 photograph by author.

beyond the rail is forbidden. In addition, visible in the lower left corner of the images is a small, reconstructed rock wall blocking a questionable footpath leading up the monument's colossal ornamental urn. The path, as well as another trail leading behind the monument, was sealed after a tourist reportedly fell to his death from the top, though no reliable references could be found to confirm this. Despite these heightened restrictions, the Deir is still one of Petra's most famous attractions and local business owners have established a small café and seated viewing area just beyond the scope of the repeated photographs, though the exhaust pipe from the café is visible in the lower right side of the modern repeat.

Figure 6.8: Closer view of the bullet holes and damage within the highest false window, or niche, of the Deir. This inset is in the center panel of the second floor, directly beneath the monument's iconic cone spire and urn decoration. Photograph by Casey Allen, 2016.

6.3.2 – The Turkmanyyia Tomb

Located just off the small paved road leading to the Bedouin Village of Umm Seyhoun and technically beyond the boundaries of the archaeological park, the Turkmanyyia Tomb is unlike most other monuments in Petra and presents unique management challenges. Dating to the mid-first century AD, the Turkmanyyia tomb exemplifies the simple and eclectic Nabataean architectural style sporting a separated crow step cornice paired with relatively basic mantels and column decorations (Taylor, 2001). The key feature of this tomb is a long intricate Nabataean inscription above what was once the door. While there are a few other small and personal inscriptions around the region, the formality and décor of the Turkmanyyia script is unmatched in Petra. Scholars have interpreted the inscription as declaring the tomb and everything in it under the protection of Dushara (the supreme Nabataean deity), as well as dictating the legal and religious requirements for anyone wishing to be interred within (Browning, 1973). The stylized calligraphy of the Turkmanyyia inscription actually reminded early scholars of writings found throughout the Sinai, as seen by Murray (1858) describing it as "Tomb with Sinaitic Inscription". It wasn't until the later-eighteen hundreds when the script was properly identified as Nabataean (Doughty, 1888).

Situated lower in the valley, the Turkmanyyia in part of the iconic red Umm Ishrin sandstone so the delicateness of its inscription is rivaled only by the intensive decay processes that surround it. Adjacent cliff walls are perforated with tafoni, sandstone drapery, and fissures while leisegang banding and iron concretions constrict water, dissolvable solids, and salt movement to particular areas and strata, resulting in the spectacular display of color and texture for which Petra is famous. Unfortunately, these processes have already had detrimental impacts on the monument itself, as the majority of what was once assumed to be the main entrance and lower portion of the monument has complete disintegrated and several fissures now intersect the entire façade, including the inscription. Some of these fissures coincide with iron banding and run all the way into the interior rooms of the tomb. With so many threats, it was imperative to assess not only the general monument features, but also its key element and context. Therefore, the Turkmanyyia tomb was divided into six panels, including contextual panels on either side of the monument, and then the panel containing the inscription was further subdivided into two more telescoping panels: one with the inscription and the immediately surrounding area and another containing only the inscription itself.

CSSI

The most damaged of the three assessed monuments, the Turkmanyyia Tomb had an average CSSI score of 67.8, well within the highest descriptive category: *Severe Danger of Erosion* (Figure 6.9). Nearly every panel scored between mid sixties to mid eighties—dangerously high for RASI/CSSI scores. The only two exceptions, panels 7 and 8 scoring 55.3 and 38.0, respectively, were supplemental panels designated to assess specific elements within broader panels/features. That said, the general panel on which they are located, panel 5, scored 64.0, which is considered *Severe Danger of Erosion*.

Experiencing most of the rock decay processes typical for sandstone, the CSSI scores for this monument identified major concerns in nearly every section of RASI/CSSI, but the most immediate issues appear to be structural. There are several fissures transecting the façade and the surrounding cliffs, some even spouting springs or vegetation. One large fissures runs vertically through the entire monument and well into the hollowed out interior as well. The disjointedness of the cliff-face makes the tomb vulnerable to undercutting and detachment of large boulders (Wolters & Müller, 2008). In fact, the majority of the monument's lower façade is completely missing, presumably due to rock fall and undercutting. These concerns are reflected in the CSSI scores, as both fissures (independent *and* dependent of lithification) and undercutting (both preparing and detached) consistently scoring high at this site. In addition, some of the smaller fissures have begun to infill with dust and sand, making fissuresol development, where physical and chemical interactions between accumulated soils exacerbate fissure expansion (Villa et al., 1995), a possible threat to the façade in the near future—though they do not appear to be an immediate problem (only scoring 1s and 2s in CSSI).

While broader structural concerns were the most intense, smaller topical decay is also greatly impacting the visual integrity of the Turkmanyyia. Aesthetical elements, such as rounding of the carved features and loss of design details, regularly warranted higher scores. Disaggregation decay processes, such as granular disintegration, crumbly disintegration, and abrasion (all scoring high in CSSI), are prominent across the façade and have effectively reduced large portions of the monument to indistinguishable ledges or pediments with the appearance of having melted. Across the entire monument, there is only one small section on panel 5 that still displays intact original stone dressing

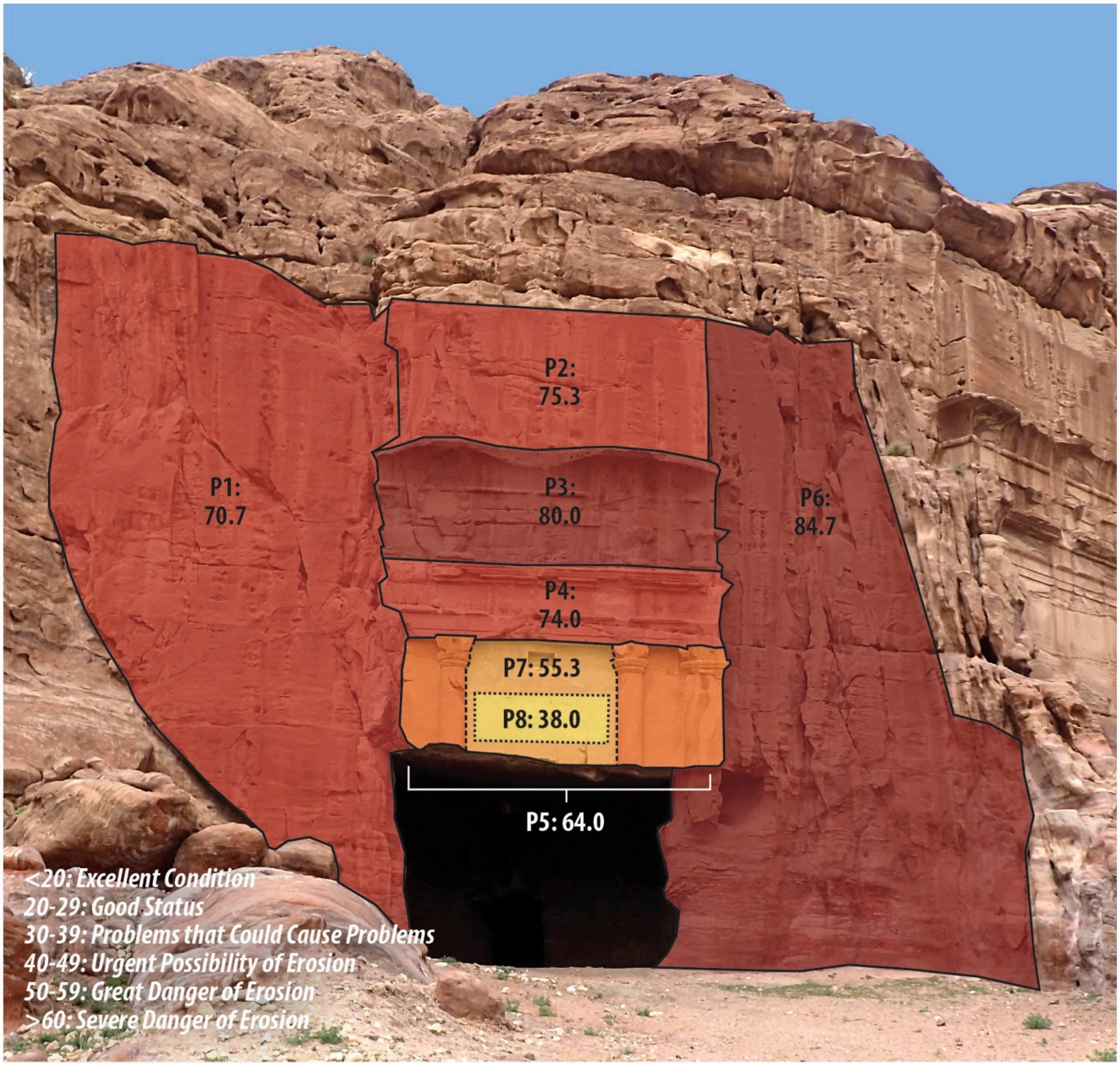


Figure 6.9: The different CSSI panels and scores for the Turkmanyyia Tomb. In pretty rough condition, the colors for this tomb begin at yellow (instead of green), to orange, to light red, to dark red signifying the highest CSSI scores and most significant areas of decay. Graphic and photograph by author, 2016.

applied after construction. Other superficial decay processes such as scaling and flaking are also concerns for this site, reflected in their high CSSI scores.

That said, the one element that makes the Turkmanyyia unique—the Nabataean inscription—is relatively stable (Figure 6.10). Illustrating the flexibility of CSSI panel designations, the Turkmanyyia assessment utilized three separate panels, at different scales, to analyze the stability of inscription. The

Figure 6.10: Section of the Nabataean inscription at the Turkmanyyia Tomb. Translations of the inscription reveal a list of social and legal conditions for interment within the tomb. The engraving also represents one of the longest and most in tact Nabataean writings in the region. Photograph by Casey Allen, 2016.

widest assessment, panel 5, encompassed the entire architectural feature on which the inscription is located, including adjacent pillars and design elements. With an average CSSI score of 64.0, this panel is within the *Severe Danger of Erosion* category and rated particularly high in independent fissures, undercutting (both impending and present), and invasive bird activity (e.g. nesting, bird droppings, etc). The next inscription assessment scale, panel 7, incorporated the dressed rectangle housing the inscription and its immediate surroundings—no other pillars or decorative elements beyond the inscription. Scoring lower (CSSI average of 55.3: *Great Danger of Erosion*), this panel excluded the severe decay occurring along the outer edges of the broader feature assessed as part of panel 5. Within this more focused area, CSSI identified the largest risks as independent fissures, inherent rock weakness, undercutting, and abrasion. The final inscription assessment, panel 8, concentrated solely on the small area actually containing writing. Working in a much smaller area than the other feature areas, this panel only scored 38.0 (*Problems that Could Cause Erosion*), with the biggest problems identified as fissures and stone weakness. The differences in these three scores exemplify the importance of context: the inscription itself may be moderately stable but the ledge on which it is located could cause problems in the future.

Repeat Photography

According to the repeat photographic analysis, the Turkmanyyia tomb has been in rough shape for some time (Figure 6.11). The tomb's recognizable missing lower half is gone in both images, though it seems some of the rock fall debris has been cleared since the 1925 photograph was taken. Abrasion and streaking from water flow and rain runoff is present in both photos, though it seems to have intensified near the top of the monument between the historic image to the modern repeat. Decay also appears to

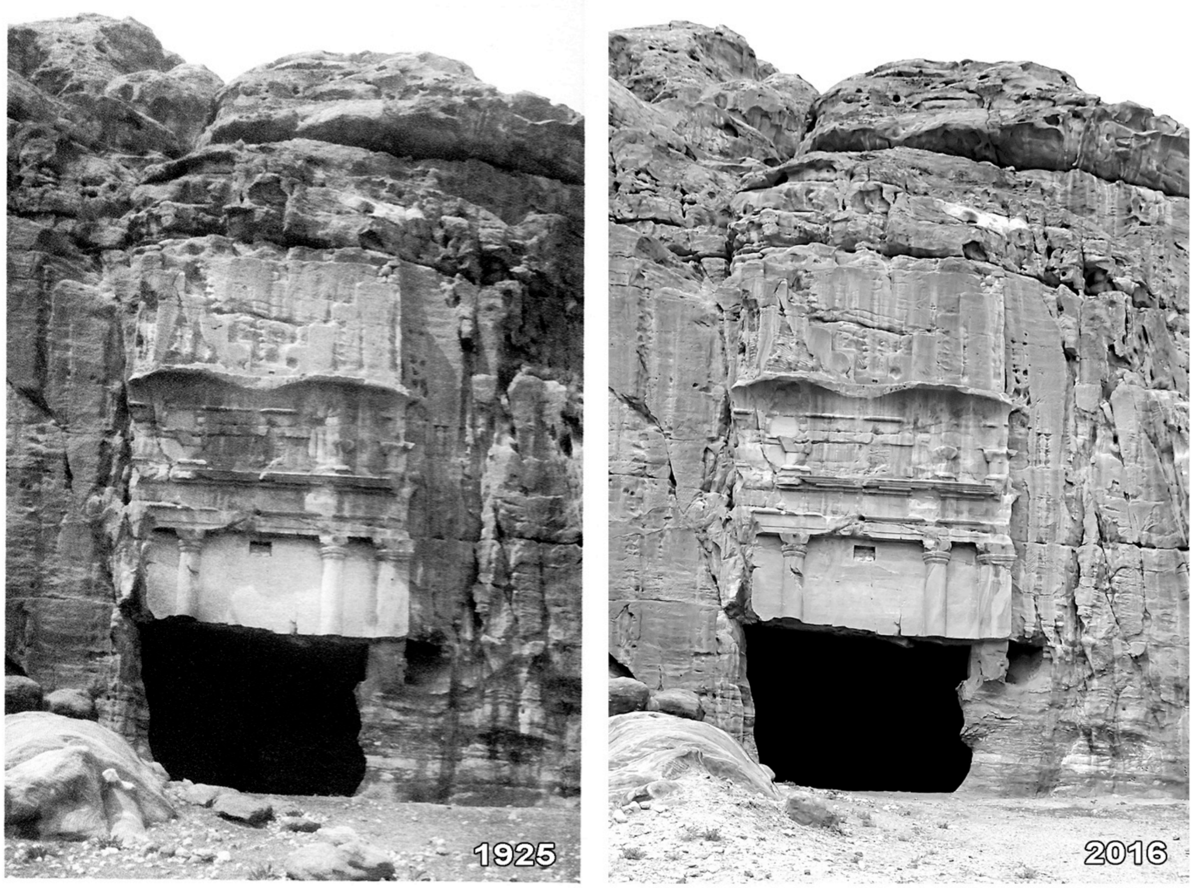


Figure 6.11: Repeat photographs of the Turkmanyyia Tomb. 1925 photograph from A. B. W. Kennedy (1925). 2016 photograph by author.

have advanced on the lower right side of the monument's entrance, where undercutting and flaking has created a small ledge in the modern repeat not present in the historic photograph. Extended beyond the doorframe, other areas of the lower context wall exhibit a greater degree of decay and loss of material.

This decay, as well as the clearing of debris, could be explained by other visible changes in the contextual landscape. The sediment and materials ramped against the boulder in the foreground and along the cliff wall at the base of the monument appear to be alluvial deposition, possibly evidence of flood activity. Nested at a nexus of multiple canyons and wadis, Petra is no stranger to flooding (Paradise, 2012). The Turkmanyyia Tomb as situated within a wadi of the same name, Wadi Turkmanyyia, with a steady enough water supply to sustain a relatively large lemon orchard and other forms of intermittent agriculture. It would be reasonable to assume this wadi has flooded at least once over the past century, possibly causing the observed difference in decay along the base of the cliff and depositional patterns. Alternatively, the rock fall debris could have been salvaged for building material and the boulders in the foreground were extremely friable when touched, making it just as reasonable to assume the differences in visible decay was the result of natural incremental deterioration. Further exploration of the site would be necessary to determine which hypothesis has the most evidence.

6.3.3 – The Lion Triclinium

Found part way up the trail to the Deir, the Lion Triclinium is located at the end of a small winding canyon. Tucked out of the sight from the main trail, the only indication of its existence is a single sign posted on the side of the monastery trail stairs. This monument is smaller than the other two selected for this case study, but is more decorative. The detailed mantels sport buttoned discs similar to those found on the Deir but are bookended with two pilasters adorned with carved masks and floral scroll-work. In addition, there are two carved lions, one on each side of the door, for which the monument was named. Somewhat uncharacteristic of late-Nabataean architecture, the masks—speculated to be Medusa—and overly stylized design of this triclinium have lead some scholars to believe the monument was actually created during the Early Roman period in Petra and not Nabataean at all (Browning, 1973). However, the striking similarities of the cornice and mantel designs with the Deir could just as easily suggest a Nabataean origin with a more liberal artistic license and heavy Roman inspiration.

Geologically trapped between the Umm Ishrin and Disi sandstones, the Lion Triclinium exhibits some very pronounced decay features and structural concerns. The most obvious of these is the warped shape of the main entrance. Conceptualized as once being a rectangular door and either square or circular window (e.g. Browning, 1973), a design common in Petra, the entrance is now a narrow keyhole shape with decay processes advancing in all directions, especially along a horizontal fissure/iron band that transects the entire cliff face. Much like the Turkmanyyia Tomb, the key features of the Lion Triclinium required a staged CSSI analysis, where general panels were assessed first, and then additional more-focused examinations were made of each lion and mask. The Dushara shrine immediately to the left of the monument was also assessed, as well as two contextual panels on either side of the main façade.

CSSI

With an average CSSI score of 56.7, the Lion Triclinium was the most stable of the three selected monuments, though it still ranked within the second highest descriptive category, *Great Danger of Erosion* (Figure 6.12). This could be due to a number of factors, possibly including its isolated setting or elevated position within the canyon. Similar to the Turkmanyyia, the supplemental panels focusing on specific design elements appeared more stable than the broader panels on which they are located. For example, both carved lions had significantly lower scores (panels 11: 62.0 and 12: 55.3) than their contextual panel (Panel 6: 70.0). With the unique location of the monument and protected surroundings, the majority of concerns identified by CSSI were superficial decay processes mostly centered on loss of detail. Decay processes such as flaking, granular disintegration, and rounding of design features scored particularly high. Large sections of the upper mantels and cornices have been completely smoothed and degraded, making them appear to have melted or dissolved. Advanced flaking, scaling, and crumbly disintegration around the edges of the monument opening serve to support the speculation that the monument once sported a separate door and window. Future loss of detail at this monument is also highlighted in its CSSI scores. Both impending scaling and flaking as well as splintering development are of particular concern. These processes could be exacerbated by tourist activity, as climbing and entering the monument is unimpeded (Figure 6.13).

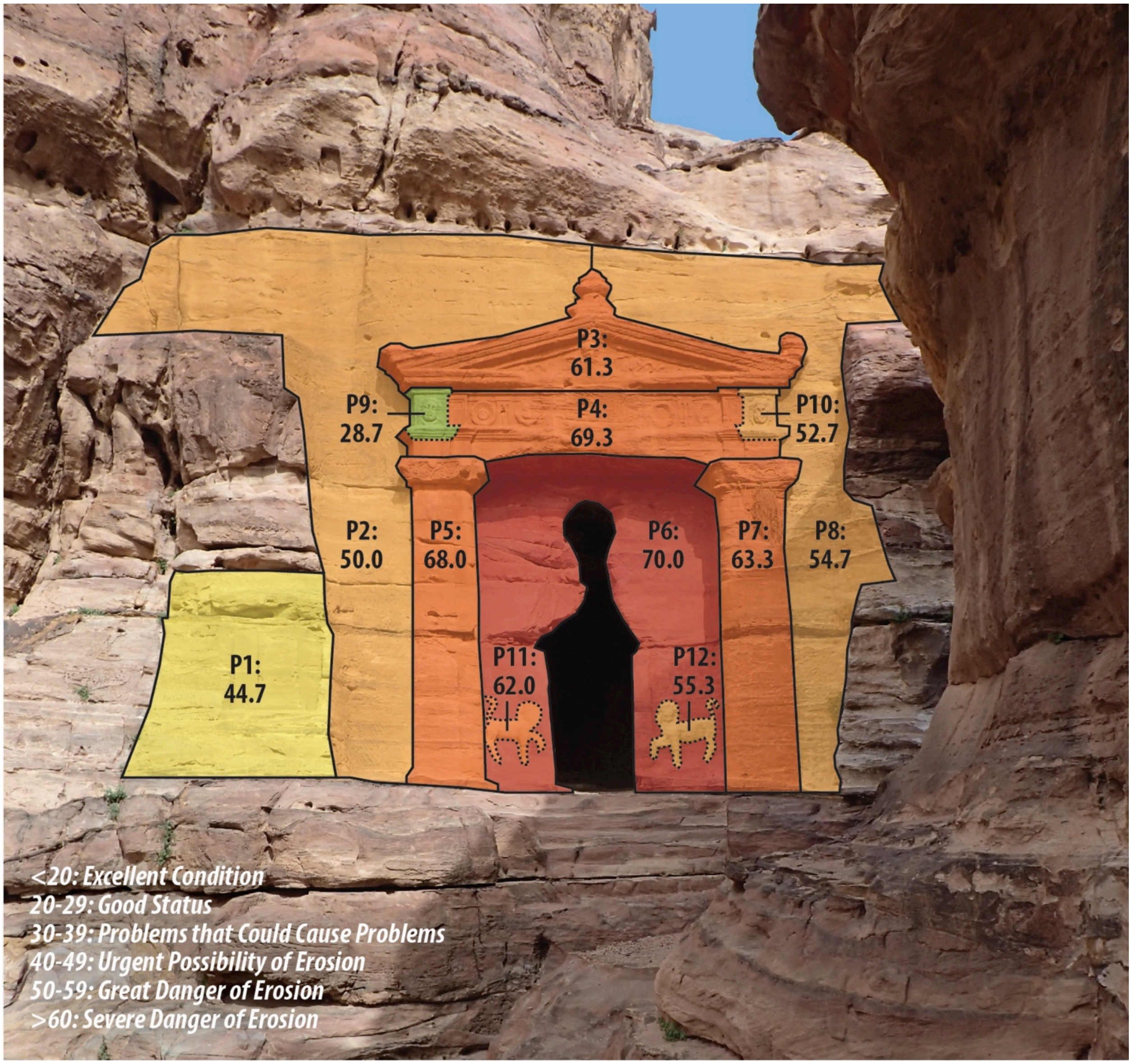


Figure 6.12: The different CSSI panels and scores for the Lion Triclinium. Colors coordinate with degree of degradation, ranging from green indicating stable conditions to yellow, to orange, to light red, to dark red signifying the highest CSSI scores and most significant decay. Graphic and photograph by author, 2016.

The monument was also not without at least a few structural issues. Most notably were fissures along the bedding plain and textural anomalies. Similar to the Deir, iron rich bands in the substrate have created natural barriers stopping the migration of salts and minerals through the sandstone. With standing water just below the monument and evidence of run off near the façade, along with plant growth on the and near the monument, water seems to play a major role the triclinium's decay—making the

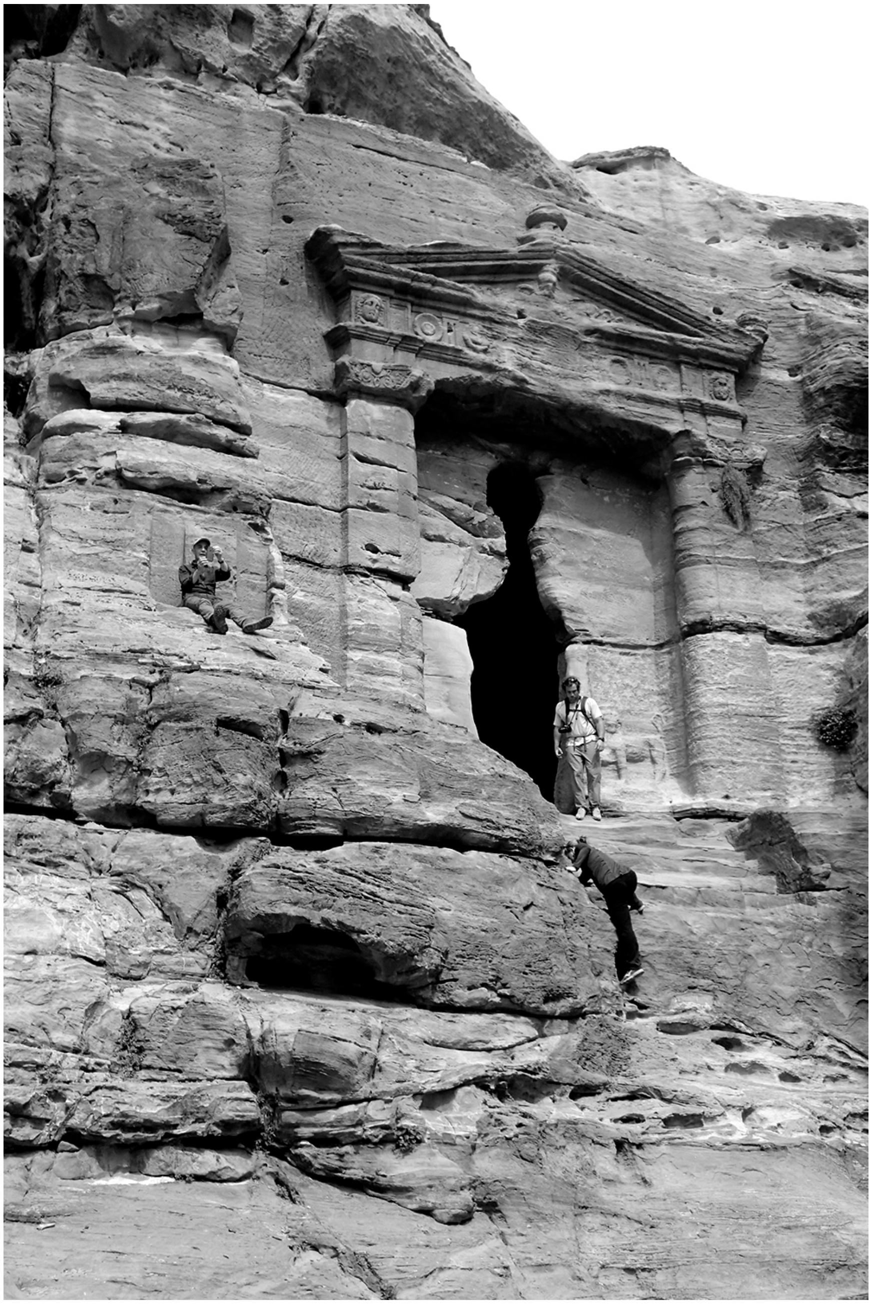


Figure 6.13: Tourists climbing and sitting on the Lion Triclinium and neighboring shrine indent. The lack of stairs for easy access or signs encouraging or forbidding such activities exacerbates the issue, as tourists only have other tourists' behavior to determine what is appropriate and what is not—which not always correct and can lead to problems (du Cros & McKercher, 2015). Photograph by author, 2016.

impermeable iron banding all the more impactful. Areas directly adjacent to the banding, for example, exhibit significantly higher rates of splintering, crumbly disintegration, and flaking.

In addition to broader feature assessments, the Lion Triclinium analysis also included four supplemental panels specifically focused on the monument's unique carved elements (Figure 6.14). A few of these features are among the most stable panels on the entire monuments. The lowest scoring

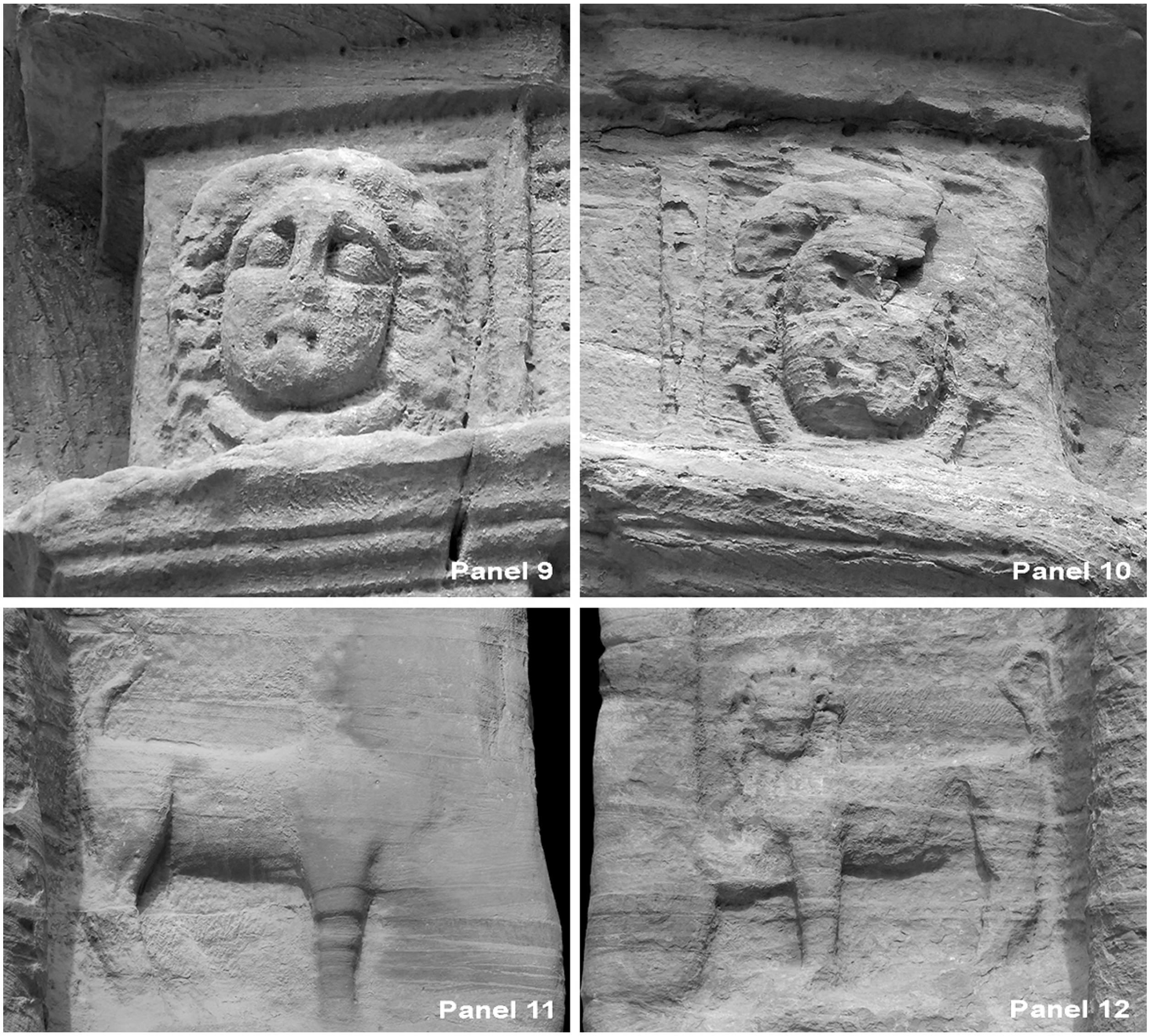


Figure 6.14: Close up photographs of the carved features on the Lion Triclinium. Demonstrating the flexibility of CSSI panel designation system, these four features on the triclinium were assessed individually as well as part of the surrounding panels. Each panel/feature displayed different decay concerns and stability conditions. Photographs by Casey Allen, 2016.

panel, panel 9: 28.7 (*Good Status*), is a delicate carved face on the upper left mantel, with the most significant threats being inherent stone weakness and textural anomalies decaying differently. The face on the other side, panel 10: 52.7 (*Great Danger of Erosion*), was not as stable, mainly due to a large missing section of material from scaling and textural issues. Both faces also rated high for granular disintegration, which basically accounts for indistinguishable loss of material/detail and deteriorating stone matrices. When paired with relatively low rock hardness (as is the case for much of Petra), granular decay can be quite devastating to delicate or detailed stone decoration—making them appear to have been erased or non-existent. For example, large portions of the iconic lions, including the left lion's face and feet, have blurred almost completely from granular disaggregation. Fortunately, the right lion, panel 12, is in slightly better condition (55.3: *Great Danger of Erosion*), though flaking and salt activities still threaten the feature's future stability.

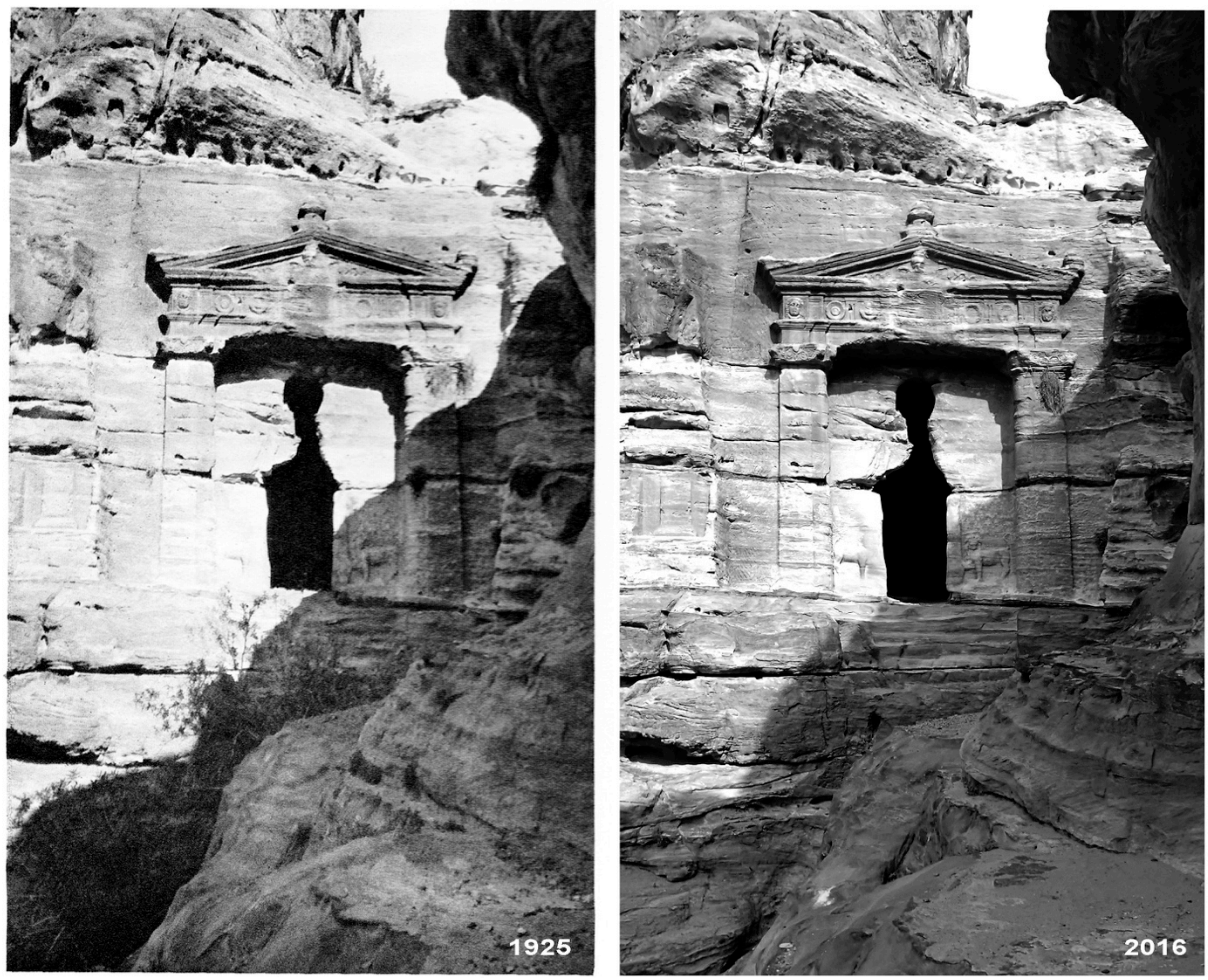


Figure 6.15: Repeat photographs of the Lion Triclinium. Since the shadow of the adjacent cliff face is so prominent in the historic image, it took three separate visits to the site to correctly replicate the photograph. 1925 photograph is from A. B. W. Kennedy (1925). 2016 photograph is by author.

Repeat Photography

Tucked away in its isolated canyon, the Lion Triclinium doesn't appear to have changed much over the last century (Figure 6.15). The most noticeable difference between the photographs deal with vegetation: The tree in the crevice below the façade is gone, the shrub growing in the fissure near the center of the right pillar is not longer there, and the tree along the Monastery trail in the upper background is not longer visible above the canyon opening. The hanging plant in the upper right column has grown, though the second plant behind it have since fallen or been removed. There also appear to be a few small ledges or loose material that have eroded since 1925, especially on the left side of the entrance along the prominent iron banding. The surrounding area also seems to have changed relatively little between the two photographs. The ledge in the foreground exhibits the most significant difference, though this could also be the result of slightly different camera angles or technological distortion.

6.4 – DISCUSSIONS AND CONCLUSIONS

Selected for their uniqueness, as well as their representativeness of Petra's awe-inspiring landscape, each of the three assessed monuments face different natural threats and management challenges. According to CSSI scores, the Deir, one of Petra's most famous monuments, is highly impacted by salts, intrinsic lithological weaknesses, and visitor impacts. Thankfully, park management has already taken steps to reduce negative anthropological influence by closing the monument entrance and prohibiting climbing on or around the façade. The Turkmanyyia Tomb, with its delicate Nabataean inscription, poses a unique challenge as it is technically beyond official park boundaries. Regular traffic to and from Umm Seyhoun, along with frequent school fieldtrips to this site, may be exacerbating the decay of this already disintegrating edifice. The significance of the inscription paired with the most prominent decay processes being structural makes the every-looming risk of rock fall at this site all the more concerning. The third monument, the Lion Triclinium, while the most stable, is still at risk of losing key design elements and carved detail due to several natural sandstone decay processes. However, these processes may be accelerated by unrestrained tourist activity, suggesting some form of access restriction/control may be beneficial.

In terms of supplemental methodology, the repeat photography served the same purpose for monuments/CSSI as it did for the Arkansan rock art/RASI (See Chapter 4): providing temporal context for decay processes and risks identified in the geologic stability scores. An excellent example of this is regarding the missing bottom portion of the Turkmanyyia Tomb. The CSSI analysis ranked undercutting, both impending and active, as major threats to the monument's stability—especially the lower panels directly above the chasm. However, both the historic photograph and concept drawing display the façade basically as it is today, indicating a relative stability and tempers the immediacy suggested by the higher CSSI scores (See Figure 6.11). By no means, does this negate the concern of undercutting causing further damage in the near future; it just provides a timeline and temporal context for that concern. The same can be said for both the Deir and Lion Triclinium as well, where vegetation and land-use changes were among the most significant visual differences.

With an expanding tourism industry and international travel becoming more accessible to the average consumer, there is an ever-increasing need to develop time and resource sensitive means of assessing the structural and geologic stability of the world's irreplaceable stone heritage. This case study has shown how pre-existing rock art decay research techniques can be suitably adapted to analyze other forms of cultural stone, such as monument facades in Petra, Jordan. The intention of RASI/CSSI is to provide a rapid field assessment to quickly catalog site stability, establish a rudimentary rock decay base-line, and to help direct future research in the most appropriate direction (Dorn et al., 2008). This makes it an excellent method for pilot studies or to address particularly large sites with an often-overwhelming number of individual stone elements. This has been a problem for establishing long-term stability management in Petra, Jordan. Attempts have been made, such as the UNESCO-led risk assessment pilot study by Paolini et al. (2012), but the employment of CSSI and other rapid field assessment techniques could help park management and the Jordanian government to develop effective conservation policies to both protect their stone heritage while also prolonging their viability as economic and tourism resources.

CHAPTER 7: DISCUSSIONS AND IMPLICATIONS

Rock art is an intricate cultural resource, incorporating various elements such as art, history, anthropology, geomorphology, and because to this, there are several different ways in which mixed field assessment tools and techniques can contribute to its management and protection. Pulling examples from the three case studies employing two such methods—RASI and repeat photography—the merits of mixed field assessments of rock art are examined thematically: theoretically, educationally, and practically. Within each theme, discussion is tied back to CRM and rock art conservation and management policy—illustrating how such merits have the potential to incite significant and necessary shifts from the conventional approach to cultural stone decay and landscape change to incorporate more, if not all, components of the cultural landscapes and heritage resources. It is important to acknowledge that this chapter explores the relevance of all three case studies only in regard to their impact on the larger fields of rock art research, CRM, and cultural tourism/landscape management. For reference to particular details or case-specific implications, see the discussions and conclusions sections of each study (i.e. Chapters 4.4, 5.4, & 6.4).

7.1 – PRACTICAL MERIT

While mixed field techniques have considerable theoretical and educational merit, their strongest and most significant contributions to rock art conservation are practical. In this discussion, 'practical' is used to encompass all matter of economic, logistical, realistic, or scientific themes and topics involved in successfully establishing informed and effecting management policies. Several integral characteristics of mixed rapid field methods, as well as what these features make possible, in rock art research have the potential to fill the widening gap between the different stakeholders engaging with the resource—whether they're conservators, tourists, or just curious locals.

Among the most intrinsic practical merits of mixed field techniques is their ability to counter methodological 'blind spots', when paired appropriately, to ensure a more holistic assessment of the landscape and rock art. Case study #1 evaluated the compatibility of RASI and repeat photography as field methods by testing them on a number of rock art sites in the Arkansan Ozarks. At all three study sites, both methods enhanced results or helped overcome short comings of the other: Detailed RASI analyses compensating for poor lighting conditions at the Narrows Rock Shelter, repeat photography revealing inherited decay (Whitley, 2001) unintentionally incorporated in the RASI scores of the Putnam pictographs, and both methods reiterating the devastating effects of lithobiont overgrowth impacting the Edgemont petroglyphs. The dual methods continued to be advantageous for evaluating the Grenadian Carib Stones in case study #2, which explored using mixed methods to assess change over time and/or as an emergency response to potential trauma. Particularly significant at Mount Rich, supplementing RASI with repeat photography provided visual representation of changes in physical condition of the petroglyphs, as well as contextualize the setting and appearance of the site—unveiling possible motivations for the local community to intervene as they did to clean the stones. For case study #3, the adapted RASI (CSSI) played a critical role in identifying serous decay issues despite the general stability suggested by the repeat photography. Even when mixed methods contradict, such as they did here, the results are still stronger than if only one had been employed—if anything else, conflicting results only make researchers look at the data even closer. In Petra, the deceivingly stable appearance of the monuments from the repeat photography may help explain the fairly casual and unconcerned social behaviors and attitudes toward monument conservation, despite the relatively significant decay found through the CSSI—critical information for CRM agencies wishing to protect Petra’s numerous cultural resources.

Another major practical strength of rapid mixed field techniques is, as indicated by the name, is the speed and relatively low resource requirements to conduct meaningful and applicable rock art research. In locations, such as the Arkansan Ozarks, where rock art geological stability assessments had never before been attempted, pairing RASI with historic repeat photography play key roles in establishing conditional base-lines for future research without demanding lengthy excavations or tedious surveys. The minimal research resources necessary (i.e. one trained individual, paper, and a pen) lessen the financial stresses for government or CRM entities responsible for managing cultural landscapes such as rock art sites. In situations when no direct governing parties exist or funding for research is limited, unprotected rock art sites, such as the Carib Stones, low costs and time requirements allow individual scholars to self-fund their research and still acquire necessary information to determine the physical status of the resource—an option rarely available for other traditional rock art decay and CRM research methods. This information can then be presented to the appropriate government officials to help incite better management policies without them having to procure any resources or money from their end, providing the agency with greater motivation or willingness to participate in future efforts (Jessamy, 2016).

Speed and cost effectiveness are even more significant merits for large and complex cultural landscapes, such as Petra, Jordan. For case study #3, the timeliness and cheap materials minimized overall research costs by limiting the necessary trips into the park—where entrance fees are becoming increasingly more expensive and research permits more difficult to obtain. In fact, all three monuments were evaluated in just a single day. But imagine how many monuments could be assessed in a week, or a month? Petra's daunting size has been one of its greatest assets and also its greatest conservation and research challenges. Almost all conditional or conservation studies conducted in Petra have been preliminary pilot studies—including this one—simply because there isn't enough time or money to expand the research to include the entire site (Haddad et al., 2015; Levy et al., 2013; Paolini et al., 2012). With mixed rapid field assessment techniques, such as CSSI and repeat photography, large expanses of the city could be analyzed in a relatively short period of time, ultimately creating an unprecedented structural and visual stability database to enhance monument management and to identify regions of the park in most need of conservation or restoration attention.

The fundamental characteristics of mixed rapid field techniques also make them ideal for threat identification and first step preliminary studies *before* conservation efforts are implemented. In Arkansas, the mixed methods quickly ascertained the status the Ozark rock art, but also discovered specific threats and concerns that require further investigation, such as the need for better flood protection at Putnam or determining the source/cause of Edgemont's rampant lichen and moss infestation. In fact, Edgemont is a perfect example of why rock art research should *precede* conservation: the floor was lowered in an attempt to discourage vandalism, however, most modern engravings are situated far from the actual rock art panels, not posing a direct threat, unlike the lithobionts that have propagated prolifically after the interior space was widened—the unforeseen consequence of well-intended but poorly researched conservation attempts. In fact, counter-productive restoration and management of rock art sites by well-meaning groups or individuals is a fairly common, and unfortunate, phenomenon worldwide (McDonald &

Veth, 2012; Sundstrom & Hays-Gilpin, 2011; Whitley, 2001). If user-friendly and approachable field techniques were made more accessible, perhaps more efforts would be made to assess rock art sites first, instead of allowing assumptions or intentional dictate conservation practices.

Not only can mixed rapid field techniques reveal previously unknown threats, but also serve as first response research methods to evaluate the impacts of known events, such as the cleaning of the Carib Stones at Mount Rich or increased tourism in Petra. Much like medical first response methods, the purpose of research immediately following a known event is to assess the extent of damage and identify the most significant concerns so that further actions can be the most productive. For Mount Rich, the greatest damage was measured immediately following the cleaning, with abrasion and removal of protective rock coating being the most concerning issues. This might insinuate the would-be conservators either scrubbed too hard or used inappropriate cleaning materials. However, after a year, a whole new form of algal coating had replaced the removed top layer of many carved stones at the site. While this is now in need of more detailed investigations, the repeated annual assessments of the Carib Stones—both the day after trauma and over a year later—revealed rock decay patterns that would have seemed largely unrelated had only one year been analyzed (i.e. exaggerating the damage from the cleaning if only 2015 values were used without a follow up, or under-estimating the dramatic speed with which the new coating developed if only 2016 values were collected). Similarly, increasing tourism in the world's great cultural landscapes, such as Petra, have the potential to initiate significant landscape changes (Baldwin, 2000; Byers, 2009; Caletrío, 2011) and the speed, ease, and breadth of mixed rapid field techniques have tremendous potential to monitor such changes. Although case study #3 only incorporated static data from a single collection period, it already identified a number of issues that may cause problems in the future. Continued monitoring and repetition of the same research methods could be critical in measuring the progression of those concerns and help CRM and governing agencies plan accordingly.

7.2 – THEORETICAL MERIT

Among the more inherent theoretical merits of observational field assessment techniques, especially visual methods such as repeat photography, are their inherent connections with the concepts of aesthetics and landscapes. Rather than being focused on specific criteria or only gathering measurements of particular features, repeat photography captures *all* visual change within the frame of the photo—the whole appearance of the landscape, corresponding with the Sauer (1925) sense of the term. With this approach, the inadvertent inclusion of overlooked or dismissed features in the space might turn out to be important in terms of the aesthetical or visual quality of the cultural resource. For example, the intended focus of case study #2 was to determine the impact of local activities on the Mount Rich petroglyphs in Grenada, and while the annual RASI analyses revealed interesting decay patterns of trauma and recovery, the repeat photography displayed the dramatic visual transitions from wild, to raw, to healing—suggesting, from a purely aesthetical view, the cleaning of the stones did benefit the clarity and appearance of the Carib Stones. It has been postured by some scholars that the aesthetics and 'beauty' of rock art are critical to encourage and sustain conservation and management efforts (Heyd, 2003; Whitley, 2001), so being able to quickly appraise the visual quality of a rock art site is vital to their survival.

Aesthetics and appearance can be deceiving, however, if misinterpreted or used as the sole criteria for stability, which could easily have been the case for the Nabataean monuments in case study #3 if multiple techniques had not been used. Owning mainly to their size and the wide scope of the historic images, the repeat photograph pairs for the Deir, Turkmanyyia Tomb, and Lion Triclinium display minimal aesthetical differences—misrepresenting the considerable decay identified in the CSSI evaluations. The repeat photography illustrated how the general landscape—the appearance/representation of the monuments and their surrounding areas (Johnston et al., 2000)—was relatively unchanged but the sandstone from which they were carved was less than stable and potentially in need of external intervention. By employing two complementary rapid field techniques, it was possible to determine both the aesthetical and structural conditions of the monuments—both values being immensely important CRM entities invested in heavily touristed and internationally recognized destinations such as Petra, Jordan (Paolini et al., 2012). That said, as postured by DeSilvey (2006), decay can also supply a certain degree of intrigue or interest to historic sites, such as Petra, so although repeat photography contradicts the CSSI scores, it could serve as a valuable tool to gage visual appeal—not only in terms of integrity and perceived beauty, but also decay, disorder, and uniqueness in its deterioration.

Tying more to sense of place, field assessment techniques provide an alternate method for people to engage with cultural landscapes and actively participate in their evaluation and management. Several studies have shown that involvement of indigenous and local communities in CRM and rock art efforts increases personal and social connections with the resource, promoting stronger interest in employing effective conservation policies and protective behavior (Allen, 2008; Goldsmith, 2014; Kalman, 2014). Although either the author or college students physically collected the data for all three case studies, a number of local residents at the field locations or site managers were present and expressed interest in the research methods and analyses—both of which non-scientists could easily participate in with future projects. In the Arkansan Ozarks (case study #1), representatives from the land owners or governing agencies escorted the research team to each site—a USFS ranger to the Narrows, a US Corps of Engineers Capitan to Putnam, a volunteer curator at Edgemont. In each case, the representative was curious and eager to learn what the RASI/repeat photography assessments revealed about their sites. If properly trained, any one of these individuals could participate in future analyses. The point being, members of the community already place value on their rock art resources—a local newspaper even came out to the Edgemont shelter for a brief interview for an upcoming issue (see Appendix J.2). The development and implementation of user-friendly field methods, such as RASI and repeat photography, can harness and enhance that interest to further promote positive behavior and sense of place related to the management of rock art sites and cultural landscapes.

7.3 – EDUCATIONAL MERIT

Not only do rapid field assessment techniques encourage the active participation of local community members but they can also play an integral part in educational and student activities engaging cultural landscapes and rock art. Allen (2008) used RASI as an alternate pedagogy to teach middle school students about rock art, stone decay, and geomorphology, with students demonstrating a significant retention of information once the project was finished—especially among student demographics largely under-represented in the sciences (minorities and females)(Figures 7.1). The encouragement and benefit to these particular students groups, alone, illustrate the power of engaged learning and the use of field assessment tools and methods in an educational setting. Similar work has

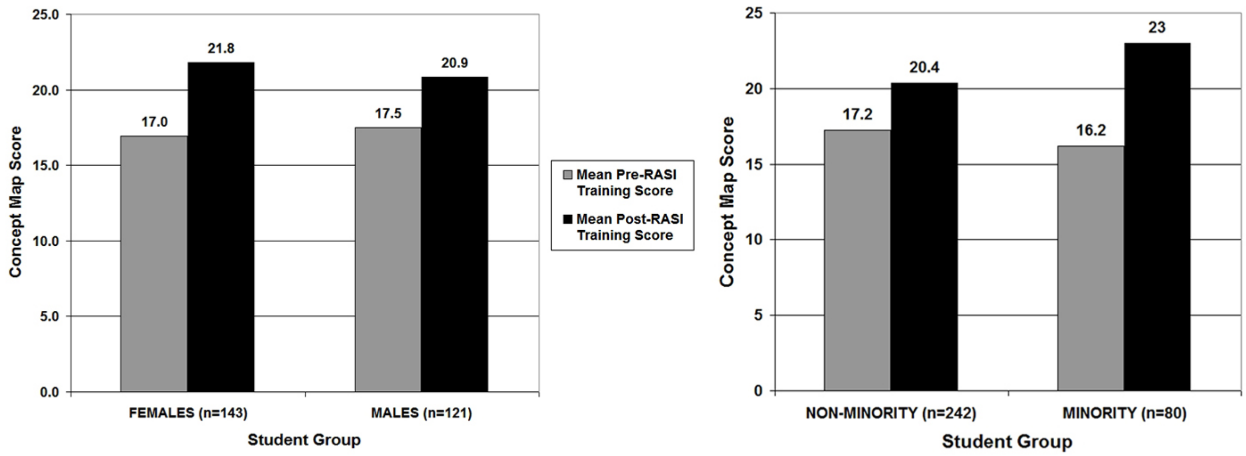


Figure 7.1 – Graphics displaying knowledge improvement after RASI training and fieldwork between male and female (left) and non-minority and minority (right) students. Scores based on concept maps taken pre- and post-field. Graphics from Allen (2008).

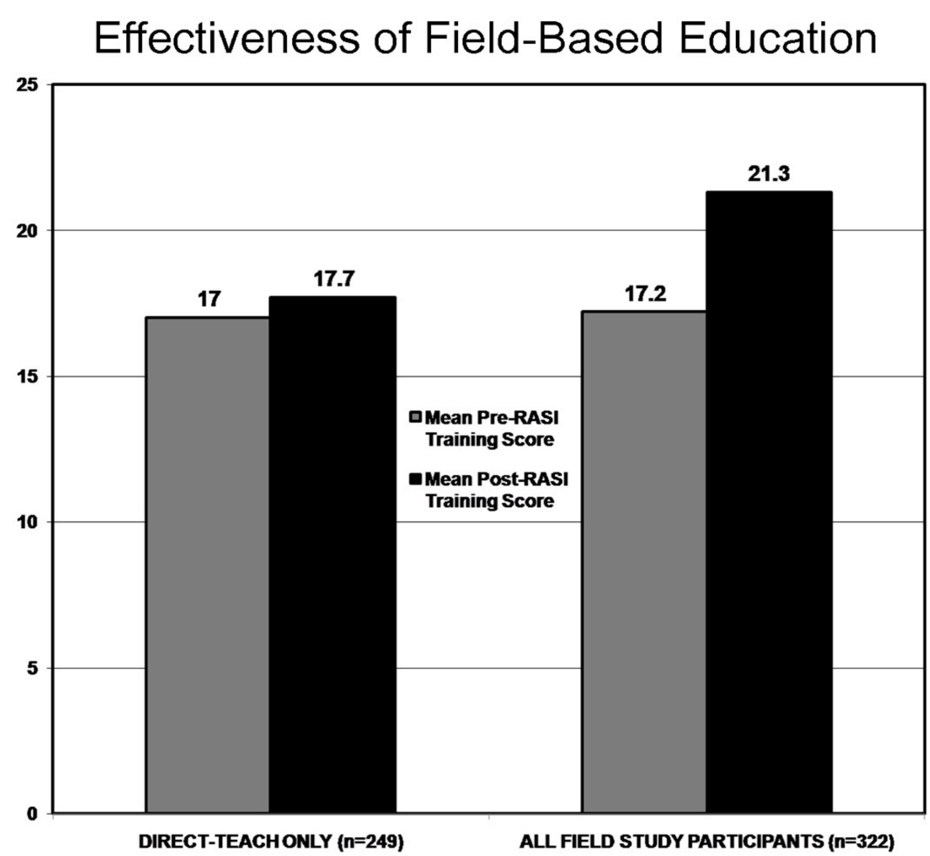


Figure 7.2 – Graphic displaying the difference between class and field-based learning using RASI as an educational medium. Not only does RASI enhance rock art and stone decay knowledge, but the employment of that knowledge in the field also promotes a greater understanding of the taught material. Graphics from Allen (2008) based on concept map scores.

also been done with college students, each exhibiting a significant improvement of concept comprehension and positive association with the analyzed rock art (Allen, 2011a; Dorn et al., 2013)—solidifying fieldwork as not only key component in geographic research but geo-education as well (Allen, 2014)(Figure 7.2).

These pedagogical merits of field assessment techniques are exemplified in the data collection for both case study #2 and #3, but in different ways. In Grenada, RASI was used to teach college students about rock art, stone decay, and cultural geomorphology, while also providing them applied research skills and experience as part of the University of Colorado Denver's short-term study abroad program *Sustainability in the Caribbean*, lead by C.D. Allen and K.M. Groom. Each year, a different group of students collected the data presented in case study #3, and each year post-program evaluations revealed significant knowledge growth/retention and a shared appreciation for rock art, both in Grenada and elsewhere (Allen, 2016). At a post-program meeting, one student from the class of 2015 reported:

> *"I will never look at rocks the same again. Because of RASI, now I see so much more and actually understand what's happening to the landscape."*
>
> *– C. D. Kennedy (2015)*

The consistency of both the pedagogical effectiveness and positive student responses to RASI from year to year only further supports previous declarations of field methods enhancing group-based education (Allen, 2014; Dorn et al., 2013). However, beyond learning, fieldwork and approachable field assessment techniques can inspire upcoming young scholars and scientists to investigate new issues in cultural landscapes and rock art research. For example, the student quoted above continued to research rock art integrity and stability in Grenada, using both repeat photography and RASI, to produce a high quality senior thesis and actively participated in co-authoring a chapter in an upcoming open air rock art management volume (Allen et al., 2017). That same student traveled to Jordan to aid in data collection for case study #3 and is now applying to numerous historic preservation graduate programs across the nation—all because she was introduced to rapid field assessment techniques as part of her undergraduate program. Imagine what other student could be inspired if exposed to fieldwork and tools such as RASI and repeat photography?

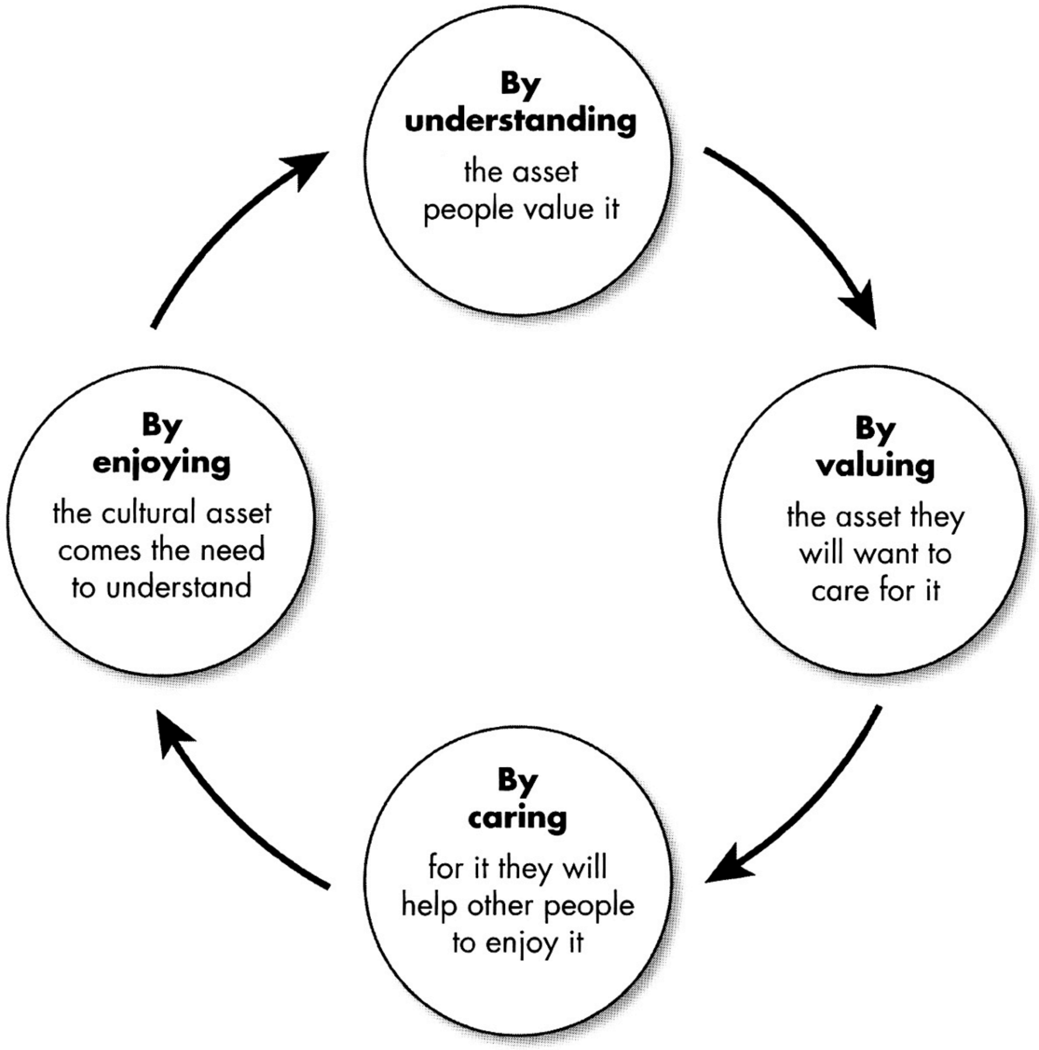


Figure 7.3: Diagram of the "Virtuous Cycle of Cultural Heritage Management" demonstrating the cyclical relationship between education and conservation efforts. Graphic from du Cros and McKercher (2015) based on Heritage (2011).

In a truly symbiotic relationship, field assessments and rock art education not only benefits students, but also the conservation of the resources themselves. Described by Heritage (2011) as the 'virtuous cycle of cultural heritage management', scholars have suggested that by promoting knowledge about cultural resources through education, locals and visitors gain a greater understanding and appreciation for the resource, thus adding additional value and desire to protect it through additional education and learning programs (du Cros & McKercher, 2015)(Figure 7.3). Numerous influential rock art scholars have also touted educational outreach and engaging local schools as the best conservational policy for protecting rock art and cultural landscapes (McDonald & Veth, 2012; Sundstrom & Hays-Gilpin, 2011; Whitley, 2001). Already proven as powerful scholastic tools, mixed field assessment techniques have the potential to bridge the gap between rock art conservators and local communities through education and active learning—as demonstrated by the local representatives in case study #1, college students in case study #2, and the enthusiast volunteer in case study #3.

CHAPTER 8 - CONCLUSIONS

Our world is undeniably complicated, including the management and conservation of its countless rock art and cultural heritage landscapes, requiring elements from a diverse and, unfortunately, fractured collection of scientific and cultural disciplines (see Figure 2.1). On top of academic over-specialization and poor cross-discipline communication, tourism and global travel place ever-growing demands on heritage resources, spreading into even the remotest locations (Theobald, 2005b), exacerbating decay and conservation concerns (Archer et al., 2005). Rock art serve as representatives of inherently fragile and exposed cultural resources particularly endangered by increasing tourism, exploitation, and/or resource mismanagement (Sundstrom & Hays-Gilpin, 2011). The need for an integrated, practical, and accessible research approach has never been more urgent. Multidisciplinary and versatile field techniques, both in theory and application, have immense potential to fill that need, as exemplified and underscored in this dissertation's three case studies, each addressing a different challenge and application of research within cultural stone decay, CRM, and heritage planning.

In the first case study, complementary field assessments using RASI and repeat photography (RP) provided much-needed empirical, aesthetical, *and* geologic stability evaluations of Arkansas's considerable rock art resources. No such study has been conducted previously, despite the wide range and distribution of Native American rock art, both pictographs and petroglyphs, across the state. Within a matter of days, the speed and comprehensive characteristics of RASI and repeat photography provided the appropriate management entity (i.e. Arkansas Archeological Survey/AAS), with rapid rock art decay assessments for three different sites, serving as representative sites in the region. With this information, the AAS can better utilize and prioritize survey and recording efforts in areas displaying greater degradation before resources are gone forever, such as the many red and black pictographs of the Putnam Rock Shelter that are already unidentifiable or the Edgemont Petroglyphs rapidly being overlain and consumed by lichen and mosses. Rock art in Arkansas still remains a sorely under-researched topic (Sabo III & Sabo, 2005), but accessible and effective mixed field techniques, such as those presented here, have the power to promote collaboration and future investigations of these irreplaceable and enchanting stone images. Incorporating field techniques and research is vital to determine the most appropriate and effective management policies moving into the future.

Unfortunately, rock art stability research often *follows* conservation efforts that have already been employed (McDonald & Veth, 2012), such as in the second case study, where RASI and repeat photography allowed researchers to determine the immediate and latent effects of local intervention at Grenada's heavily visited and culturally significant petroglyph sites: Mount Rich and Duquesne Bay. Containing some of the best examples of Arawak Amerindian rock art in the Lesser Antilles, Grenada's Carib Stones hold tremendous historical and archaeological importance (Dubelaar, 1995), but they also serve as tourist destinations and economic resources critical to struggling local communities—a complicated duality common in many developing nations. Existing within this nexus, maintaining resource longevity and aesthetics is required not only for posterity but to sustain livelihoods and employment, sometimes leading to well intended but potentially detrimental restoration attempts (Whitley, 2001). In Grenada, the local cleaning of the Mount Rich Carib Stones may have made the carved figures easier to see, but it also damaged the panels' beneficial rock coatings and made way for the new algal coatings, whose long-term influences are yet to be determined. At Duquesne Bay, poor design and limited drainage of the erected retaining wall, despite the barrier preventing the subterranean petroglyphs from being consumed by beach sand, have lead to extensive water damage and surface destabilization. At both sites, the Carib Stones serve multiple purposes and, as such, research and management efforts *must* acknowledge this reality by employing more holistic research methods capable of addressing the multiple aspects of the resources. The intrinsic merits of rapid field techniques, especially when complementarily paired, provided valuable information on the physical condition, as well as the visual quality, of the resources without requiring substantial funding/time or negatively impacting the rock art.

Reaching beyond rock art, mixed field techniques are tremendously valuable conservation and management tools to address the stability of various forms of cultural stone, as exemplified in the third case study, where existing rock art field techniques were successfully adapted to evaluate monument and building façade deterioration in Petra, Jordan. The intimidating size and bureaucratic management of the ancient city of Petra has deterred implementing valley-wide cultural stone stability research—limiting most investigations to specific monuments or pilot studies rarely leading to larger investigations (e.g. Haddad et al., 2015; Paolini et al., 2012; Paradise, 2010). Regardless of prevalent local perceptions of monument immortality and ever-increasing tourism demands and development, Petra's monuments continue to deteriorate without any comprehensive stability monitoring or the establishment of geologic baselines by which future decay can be quantified. This lack of information has effectively crippled the CRM and tourism administration of this vastly popular and globally acclaimed World Heritage Site by confining management to blanket policies that neglect to address localized decay that is steadily consuming the city. Using mixed rapid field techniques, three researchers were able to analyze and identify significant stability concerns, along with visualize centennial aesthetical change, of three major monuments in a single day—imagine what could be accomplished in a month or a summer? For all three locales, lithologic and surface decay features were quickly recognized as serious issues and each façade was divided into easily identifiable panels to aid conservation prioritization and risk management. Repeat photography also revealed significant landscape patterns—the most notable being the startlingly little visual change that has occurred over the past century. These patterns begin to explain current seemingly-indifferent management approaches and false perceptions of stability. Similar to Grenada, Petra is both a World Heritage Site *and* major tourist destination and key economic resource for the Kingdom of Jordan. Future applications of mixed field techniques would allow Petra's numerous stakeholders and researchers to establish conditional baselines, determine degrees of monument degradation, and assess visual quality, all without impeding the continual use and visitation of the site vital to maintaining local economies and businesses.

Ultimately, rock art and cultural stone represent much more than just simple drawings on rocks or old buildings—they tell a story: the story of us. They illustrate human exploration and travel across the globe. They show us the endless creativity and artistic expression of past civilizations. They reflect people's changing perceptions of the landscapes around them and where we fit in it all. Rock art can serve as a humbling reminder of where we come from and, in a way, how far we can go. Safeguarding such resources not only protect these stories, but also the budding economic and consumption markets that have erected around them. World-renowned heritage tourism sites, such as Wadi Rum, Jordan, or Mont Bego, France, meld the majestic beauty of nature with the incredible story of peoples' existence carved in the landscape. Such destinations rely heavily on the prolonged survival of their rock art resources to generate tourism and local economic growth. Without scientific research and/or detailed conditional assessments, the counter-productive or negligent policies that have plagued the world's rock art sites for centuries will continue to compromise the integrity of not only the considerable ethnographic and historical value of such sites, but also their long-term viability as economic and tourism resources (Whitely, 2001). Inexpensive rapid field techniques have the unique ability to fit this critical research need, especially for newly discovered or remote rock art sites, which usually lack sizeable financial backing or prior research experience.

The possibilities for future research integrating these inter- and multi-disciplinary approaches are both endless and exhilarating. In far too many CRM and rock art research textbooks, the physical aspects of the resource are either ignored or minimally addressed compared to the cultural, ethnographic, and content of the images (McDonald & Veth, 2012; Sundstrom & Hays-Gilpin, 2011; Whitley, 2001). However, with the implementation of observational mixed field techniques and assessments, it is possible to incorporate both the tangible *and* anthropological elements of rock art sites around the world—incorporating both content *and* context. Future research utilizing RASI and repeat photography could include a deeper elaboration of any, or all, of the presented case studies. Rock art assessments in Arkansas could be expanded to include all rock art sites featured in Dellinger's historic survey photograph collection held by the University of Arkansas Museum. Monitoring of Grenada's Carib Stones at Mount Rich and Duquesne Bay could continue annually to get a better sense of long-term recovery at Mount Rich and to determine if the new drainage system at Duquesne Bay is effective. For Petra, further investigations of monument stability and aesthetic change is sorely needed and would be considerably helpful to the Park Authority, UNESCO, and the Jordanian Department of Antiquities to better establish tourism management and effective monument conservation. Beyond RASI and repeat photography, further examinations are required to identify and assess the influence of the black algal coatings at Mount Rich, Grenada, and determine the cause and impact of the lithobiont overgrowth within the Edgemont Rock Shelter, Arkansas. In addition, rapid field techniques can be paired with existing archaeological technologies, such as DStretch—software designed to digitally enhance faded pictographs for clearer documentation (Brady & Gunn, 2012; Gunn et al., 2010), to help transition traditional research approaches into a more inclusive and well-rounded multi-disciplinary framework.

This is not the first time these methods have been validated (i.e. Allen et al., 2017; Cerveny et al., 2016; Groom, 2016a; Webb et al., 2010) but method validation is not the purpose of this research. Over-specialization and isolation of science from practice, theory from application, it is far too easy to slip into a myopic research agenda or Malthusian indifference, simply assuming technology will be developed to provide the perfect tool to conserve our world's stone heritage. This is a potentially dangerous attitude, aptly exemplified by Petra's continued deterioration because its monuments *appear* stable, despite research stating otherwise. Ultimately, the purpose of this dissertation was to present an alternative solution to this problem, a different and more-inclusive perspective. The methods already exist, but the fundamental frameworks, integration, and applications must change. The three case studies presented here demonstrate the profound potential and applicability of more trans-disciplinary and holistic approach to CRM and heritage science through mixed field assessment techniques—something desperately needed in today's divergent academic and scientific communities:

- *RASI/RP can quickly and effectively identify significant management and stability issues—e.g. destructive lithobiont activity at Edgemont, Arkansas*
- *RASI/RP are effective risk management and emergency response tools to assess accrued damage or inappropriate interventions—e.g. analyzing the impact of cleaning the Mount Rich Carib Stones, Grenada*
- *CSSI/RP widen the scope to address more forms of cultural stone and illuminate the often-dangerous discrepancies between perception and reality—e.g. highlighting the dire state of Petra's monuments despite local indifference/widely held opinions of the city's architectural invincibility*
- *Repeat Photography provided critical aesthetic data to visually contextualize geologic stability assessments and local attitudes toward the resources—information impossible to determine from RASI/CSSI alone*
- *The accessibility and intrinsic characteristics of mixed field techniques make them ideal tools for initiating multi-stakeholder investigations or preliminary research at under-funded and/or remote locations*

To counter the debilitating divide between CRM/rock art conservators, tourism managers, and researchers, multidisciplinary collaboration is more critical than ever to ensure the long-term survival of cultural heritage resources in our increasingly complex and dynamic global system (Kalman, 2014). As expressed in this dissertation, mixed rapid field techniques—inexpensive, non-time consuming, and approachable to anyone regardless of background or previous knowledge—represent the future of rock art/CRM research, all while being supported by strong theoretical and educational foundations. Promoting a multi- and interdisciplinary approach to rock art analyses through universal research tools is the key to initiating more pragmatic cultural heritage management and continued research of the world's irreplaceable rock art and cultural stone landscapes. As global tourism continues to grow at dramatic rates, having surpassed one billion leisure travelers annually (Theobald, 2005), rock art sites represent countless cultural sites caught at this confluence of heritage conservation and economic development, history and business. To ensure the survival of both aspects of these irreplaceable stone resources—both their immense cultural value as well as their economic viability—it is vital to understand their decay and the visual impact of natural and anthropogenic influences. As demonstrated throughout this dissertation, advancements in technology are not necessary to revolutionize CRM and rock art research. Instead, accessible and reliable analog assessment methods (e.g. RASI and RP) are the key to unifying rock art researchers from the divergent academic and professional disciplines determined to safeguard the world's stone imagery. Ultimately, the development and promotion of mixed rapid field techniques in cultural geomorphology, CRM, and rock art research would not only supply management entities with critical information to better protect our global stone heritage, but also provide a conduit to enable future scientific and academic collaboration for generations to come.

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APPENDICIES

A – Contextual photographs of the rock art sites from Case Study #1

B – Selected RASI sheets and photographs from Case Study #1

C – Contextual photographs of the rock art sites from Case Study #2

D – Selected RASI sheets and photographs from Case Study #2

E – RASI Element Comparisons for Duquesne Bay

F – RASI Element Comparisons for Mount Rich

G – RASI vs. CSSI score sheets comparisons

H – Contextual photographs of the monuments from Case Study #3

I – Selected CSSI sheets and photographs from Case Study #3

J – Selected photographs of author in the field

Appendix A:

Contextual photographs of the rock art sites from Case Study #1

A.1 – Cave entrance for the Narrows Rock Shelter. The majority of rock art are located on the left side of the shelter beyond the scope of the image. Photograph by author, 2014.

A.3 – Looking down the Putnam Bluff from main excavation area. Two researchers from the Arkansas Archaeological Survey and a US Corps of Engineers representative are at the base for scale. Photograph by author, 2014.

A.4 – The Putnam Bluff from Beaver Lake. With the inundation of the reservoir, the easiest way to reach the Putnam shelter is by boat. Previous access was by repelling down the bluff or climbing up to the shelter, both being quite treacherous. Photograph by author, 2014.

A.5 – The entrance of the Edgemont Rock Shelter with golf cart, survey equipment, and Arkansas Archaeological Survey employee for scale. The even cave floor and manicured surroundings exemplify the human intervention that has taken place at this site. Photography by author, 2014.

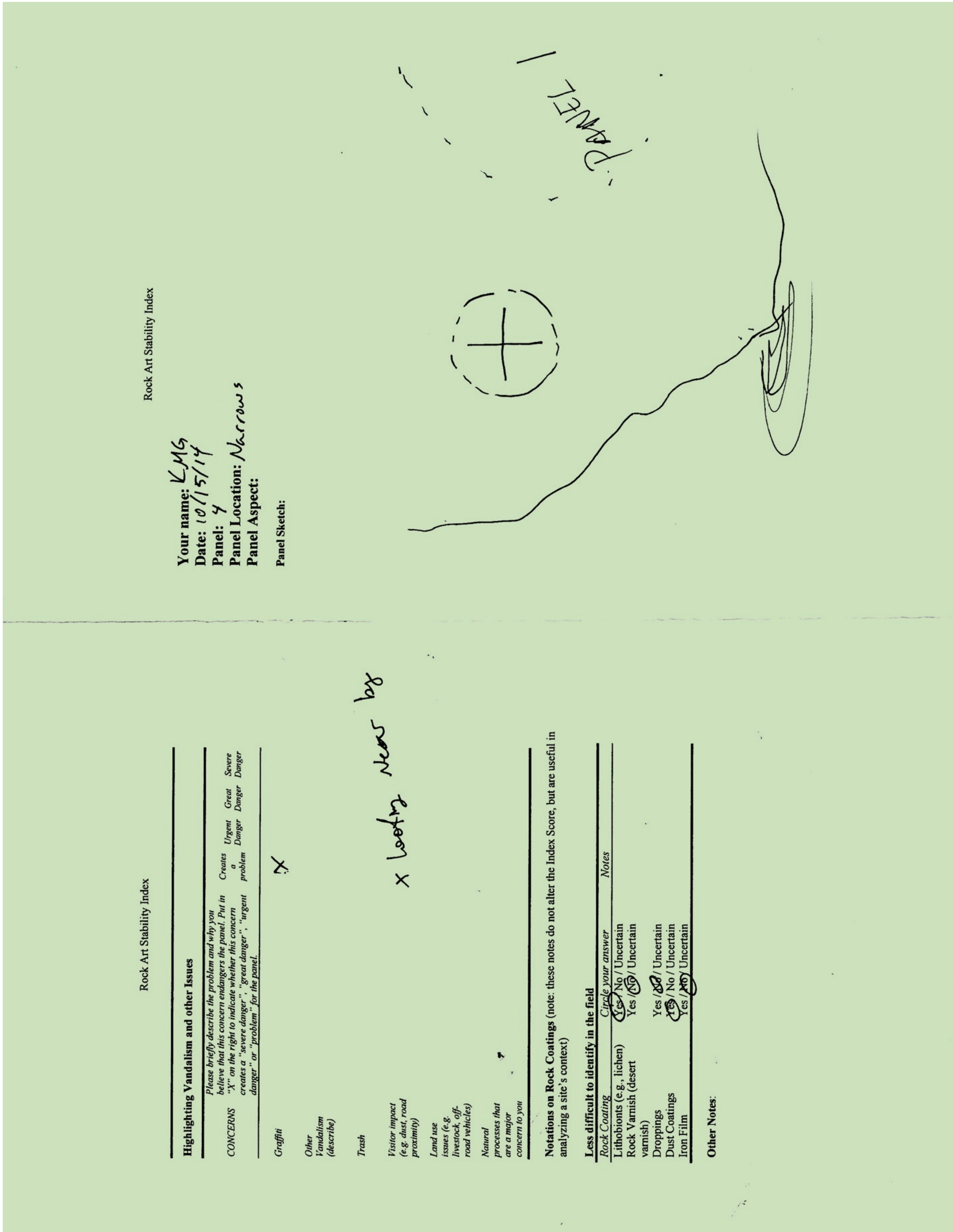
A.6 – Primary wall containing petroglyphs at Edgemont with ladder and sign for scale. From this distance the rock art is extremely difficult to see due to the rampant lichen and moss growth that covers most of the wall. Photograph by author, 2014.

Appendix B:

Selected RASI sheets and photographs from Case Study #1

B.1 – The Narrows Panel 4. Poor lighting within the shelter made properly photographing the panels difficult—even the clearest photos were still slightly out of focus or blurry, such as this one. Although this panel was on the same surface as Panels 2 and 3, they were all surveyed separately by the AAS and the RASI panel definitions were based on AAS documentation. Photograph by author, 2014.

B.2 – Front and back of completed RASI score sheet for the Narrows Panel 4.



Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti		X			
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)	x looting near by				
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Rock Art Stability Index

Your name: KMG
Date: 10/15/14
Panel: 4
Panel Location: Narrows
Panel Aspect:

Panel Sketch:

B.3 – Centerfold of completed RASI score sheet for the Narrows Panel 4.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three ***can't*** scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow)	0	1	2	3

Looting + graffiti

Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

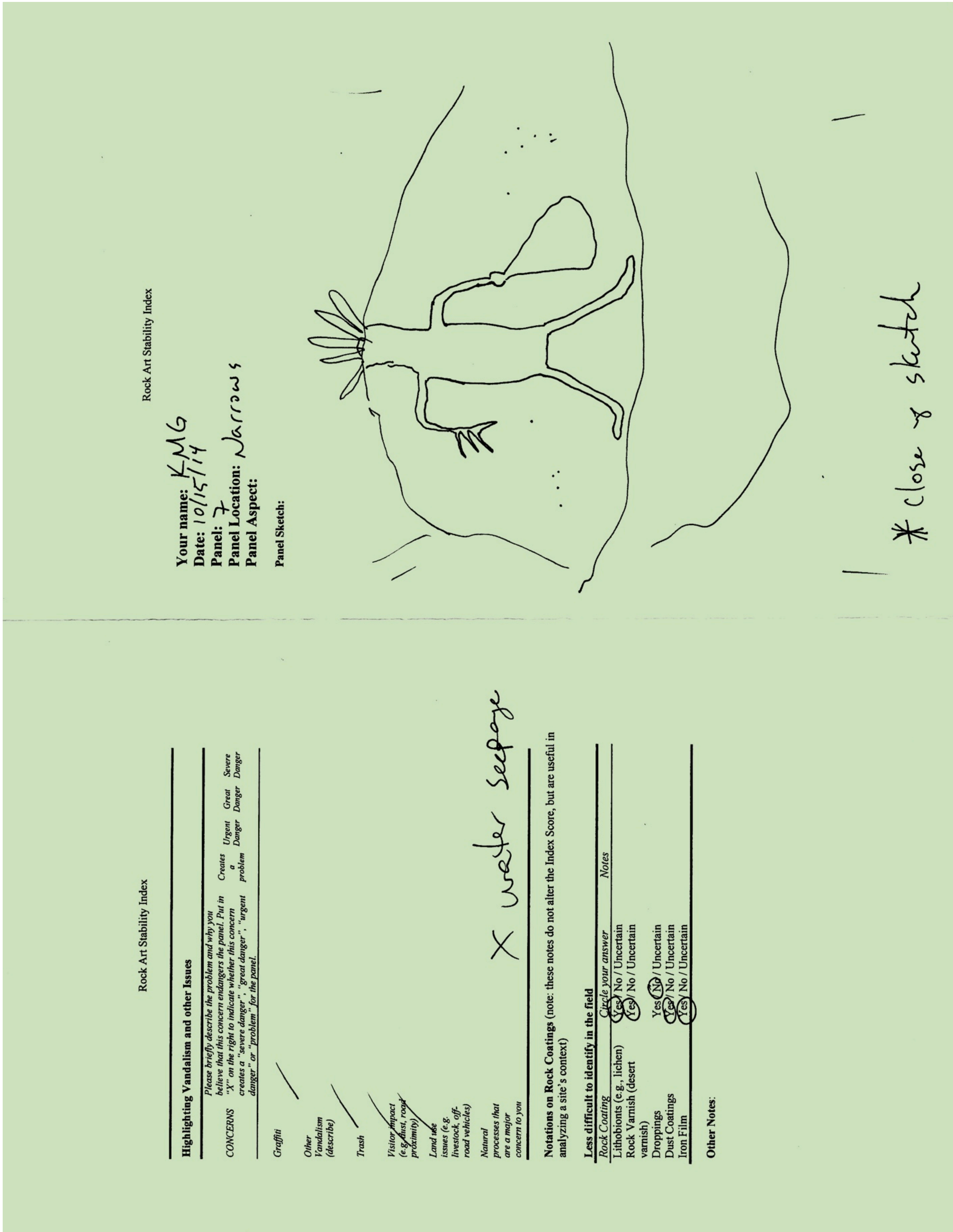
Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization/tafoni (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Mud, water, Near floor

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	-1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	-1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

B.4 – The Narrows Panel 7, containing of the most well known petroglyph at the Narrows. The sharp lines and fairly goo condition of the motif is reflected in its RASI scores. Photograph by author, 2014.

B.5 – Front and back of completed RASI score sheet for the Narrows Panel 7.



Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you	X water seepage				

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Rock Art Stability Index

Your name: KMG
Date: 10/15/14
Panel: 7
Panel Location: Narrows
Panel Aspect:

Panel Sketch:

* close of sketch

B.6 – Centerfold of completed RASI score sheet for the Narrows Panel 7.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three ***can't*** scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow)	0	1	2	3

Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

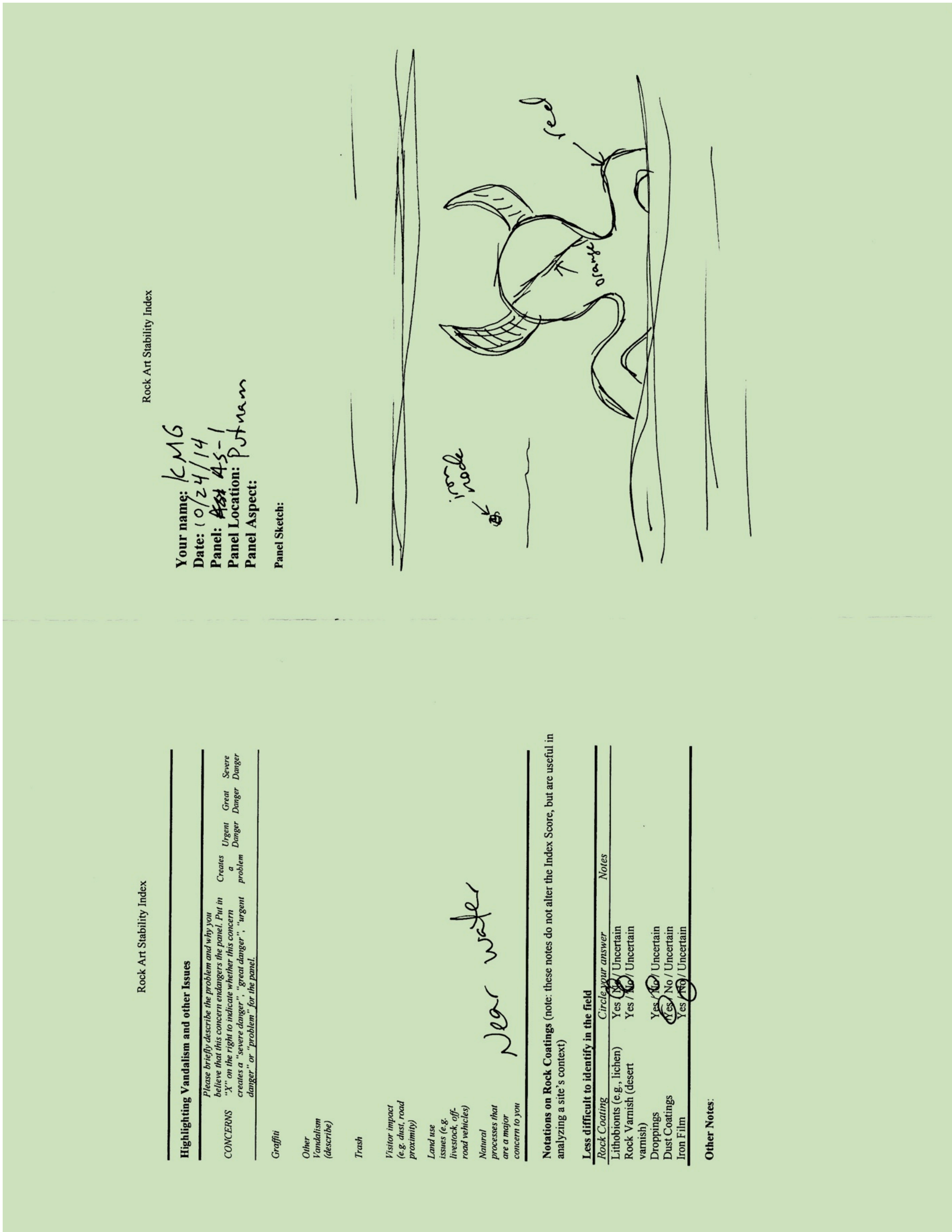
Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization/tafoni (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

- water dripping

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	-1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	-1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

B.7 – Putnam Panel AS-1, commonly called “the Buffalo”. Although this panel was actually at an adjoining site, its uniqueness in motif, design, and quality earned its inclusion in this case study. The panel is also different from most of Putnam in that it is clearly visible from the water, although it is difficult to reach on land. Photograph by author, 2014.

B.8 – Front and back of completed RASI score sheet for Putnam Panel AS-1.



Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you	Near water				

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Rock Art Stability Index

Your name: KMG
Date: 10/24/14
Panel: ~~AS1~~ AS-1
Panel Location: Putnam
Panel Aspect:

Panel Sketch:

B.9 – Centerfold of completed RASI score sheet for Putnam Panel AS-1.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three *can't* scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow)	0	1	2	3

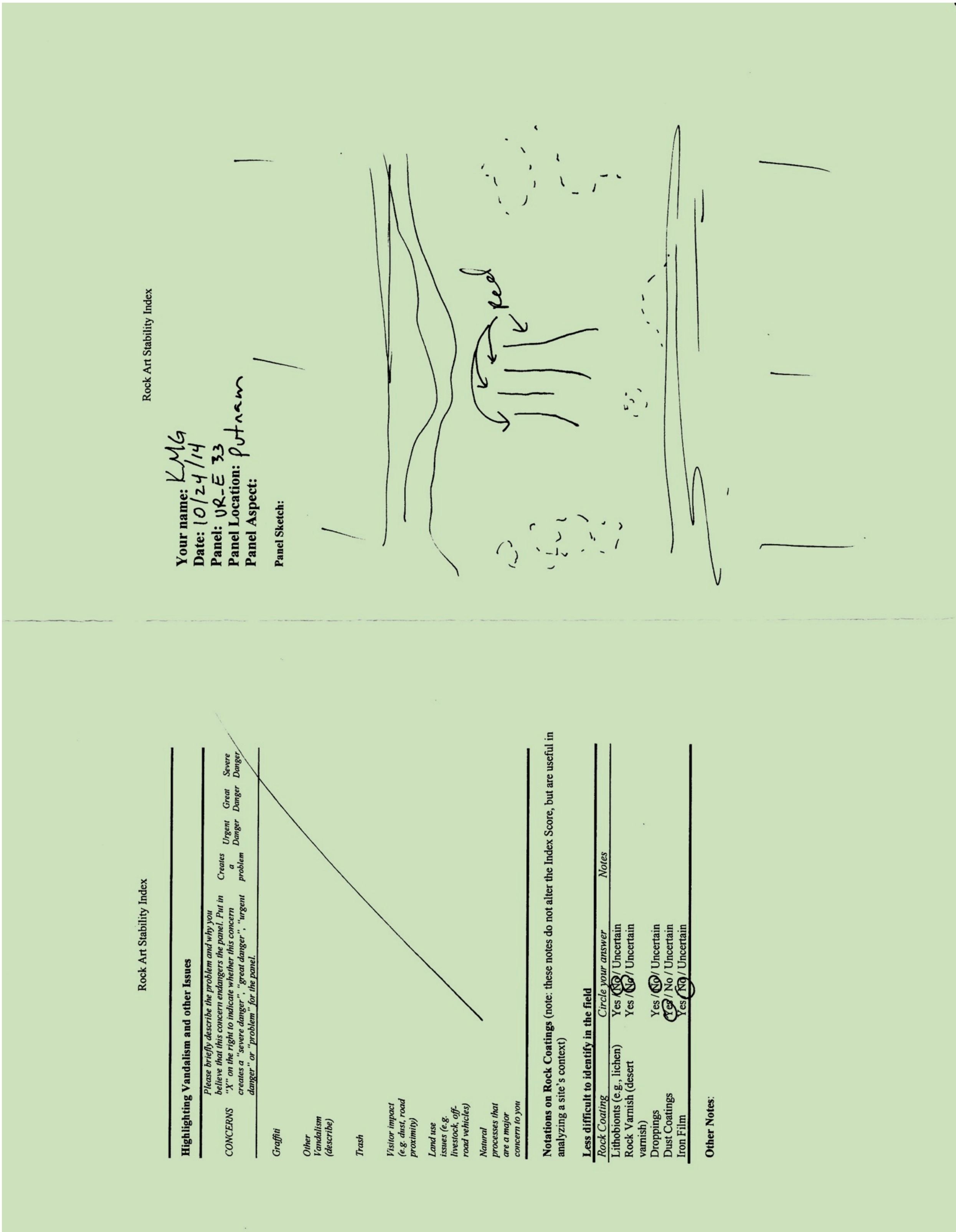
Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization/tafoni (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	-1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	-1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

B.10 – Putnam Panel UR-E 33, consisting of four red vertical lines. During the evaluation of this site, several previously undocumented panels were found, earning them the designations ‘UR-E’: Un-Recorded Element—such as this one. Panel UR-E 33 is located above and slightly to the right of Panel 1 in the AAS survey reports. Photograph by author, 2014.

B.11 – Front and back of completed RASI score sheet for Putnam Panel UR-E 33.


Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Rock Art Stability Index

Your name: KMG
Date: 10/24/14
Panel: UR-E 33
Panel Location: Putnam
Panel Aspect:

Panel Sketch:

B.12 – Centerfold of completed RASI score sheet for Putnam Panel UR-E 33.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three ***can't*** scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow)	0	1	2	3

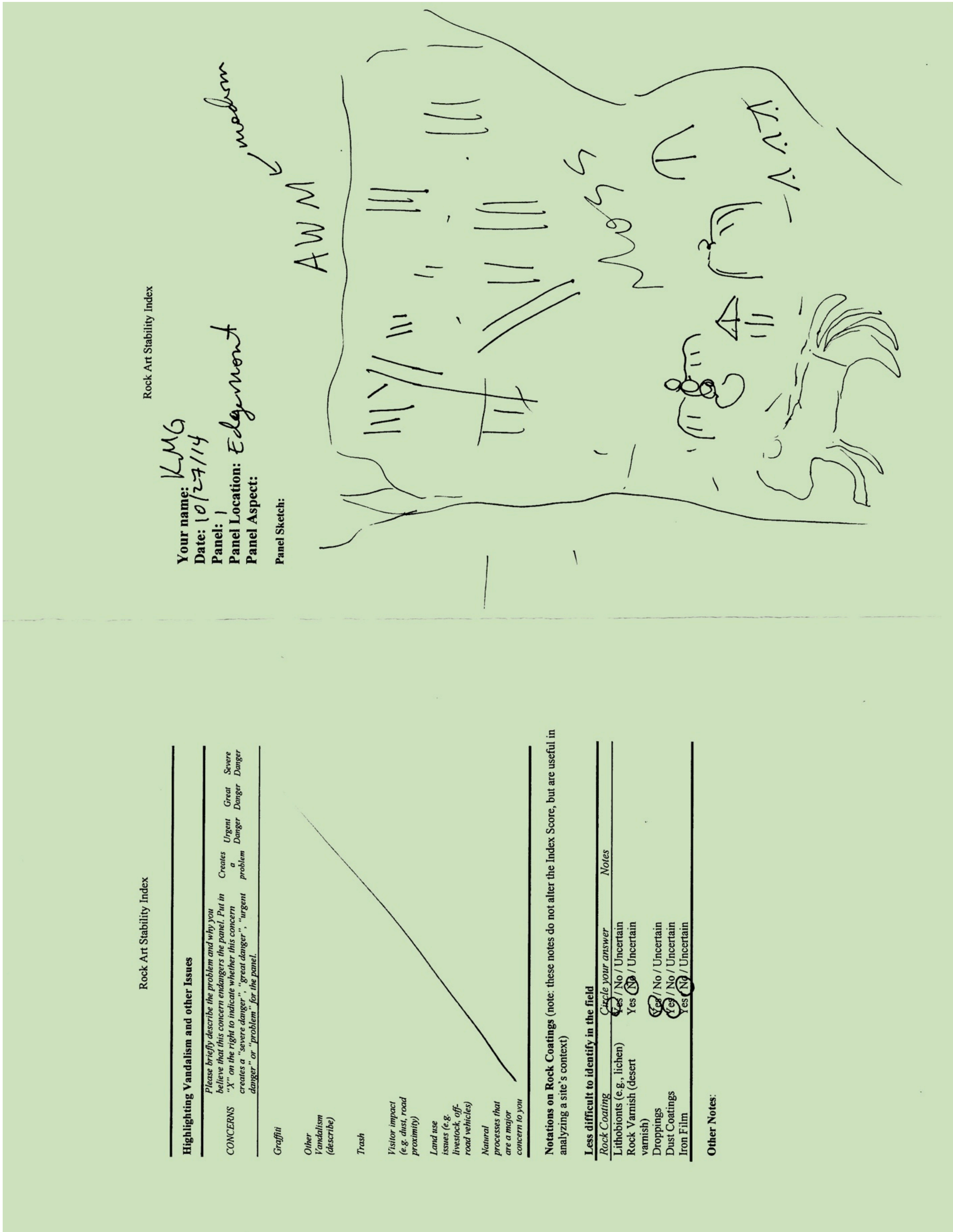
Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization/tafoni (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	-1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	-1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

B.13 – Edgemont Panel 1, near the opening of the cave. While there were historic images of this panel as well, poor lighting and moss activity made collecting an accurate repeat prohibitively difficult. Photograph by author, 2014.

B.14 – Front and back of completed RASI score sheet for Edgemont Panel 1.


Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Rock Art Stability Index

Your name: KMG
Date: 10/27/14
Panel: 1
Panel Location: Edgemont
Panel Aspect:

Panel Sketch:

B.15 – Centerfold of completed RASI score sheet for Edgemont Panel 1.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three ***can't*** scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow)	0	1	2	3

Moss/ Vandalism

Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

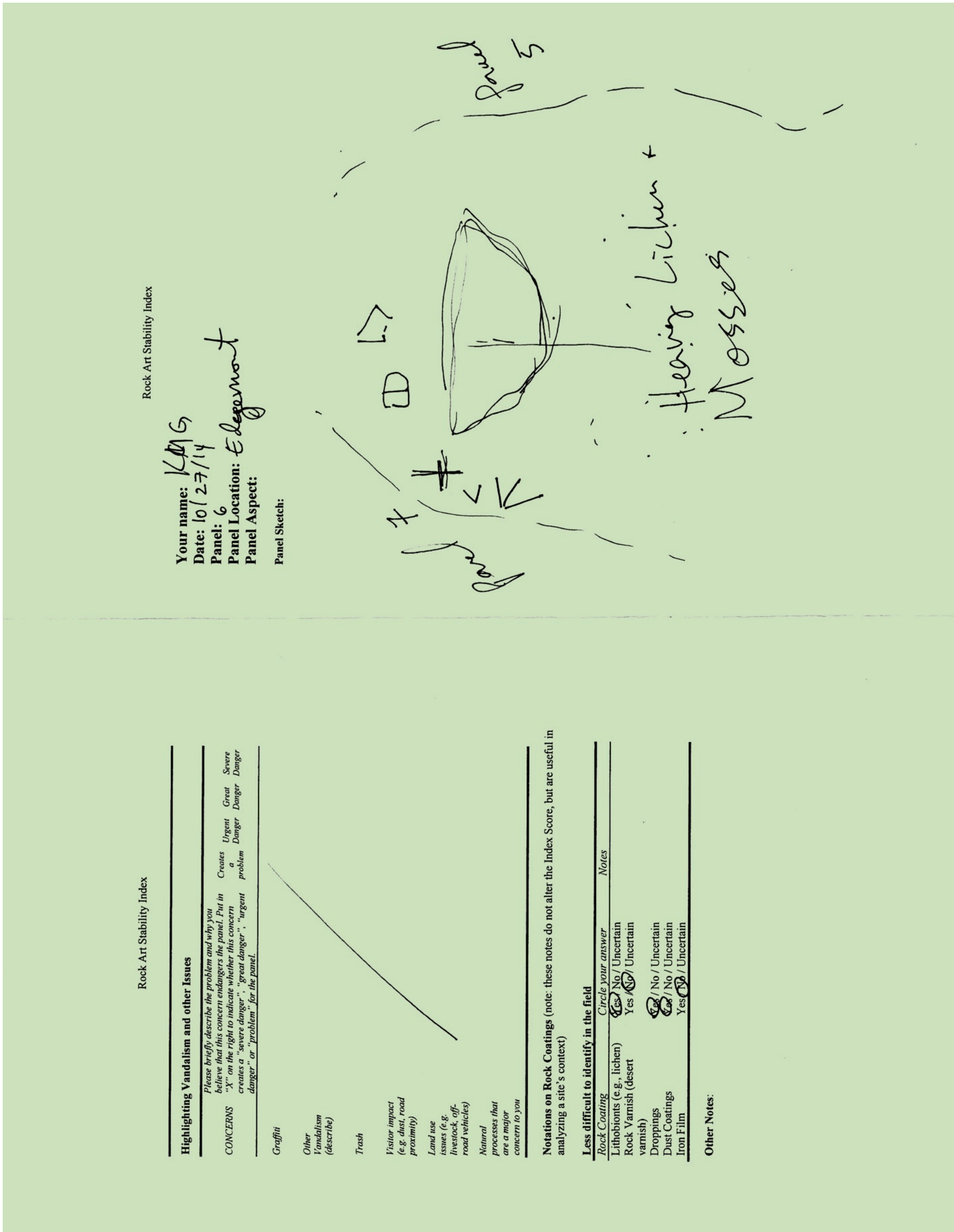
Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization/tafoni (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Moss

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	-1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

B.16 – Edgemont Panel 6, near the center of the main rock art wall. Covered in lichen and moss, the individual details of the petroglyphs are largely obscured and rock decay forms were also potentially hidden by the copious lithobionts. This panel is located on the main petroglyph wall between panels 5 and 7. Photograph by author, 2014.

B.17 – Front and back of completed RASI score sheet for Edgemont Panel 6.



Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Rock Art Stability Index

Your name: KMG
Date: 10/27/14
Panel: 6
Panel Location: Edgemont
Panel Aspect:

Panel Sketch:

B.18 – Centerfold of completed RASI score sheet for Edgemont Panel 6.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three ***can't*** scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow)	0	1	2	3

Major moss problem

Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization/tafoni (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Big Issue

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	-1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	-1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

Appendix C:

Contextual Photographs of the rock art sites from Case Study #2

C.1 – Facing the front side (panel 1) of the primary boulder at Duquesne Bay with surrounding features. Panel 3 is further down the coast and beyond the scope of this image. Photograph by author, 2015.

C.2 – The backside (panel 2) of the main boulder at Duquesne Bay with Dr. Casey Allen and Cayla Kennedy conducting RASI assessments (Permission acquired from both individuals). The new drain being beneath the retaining wall is visible in the lower right corner of the image. Photograph by author, 2016.

C.3 – Image of the small boulder (center beneath the tree) housing panel 3 at Duquesne Bay and surrounding boulders. Facing the ground, it is very likely this boulder was once upright and has since fallen, leaving the panel in a fairly precarious position. Photograph by author, 2016.

C.4 – View looking upstream at the Mt. Rich rock art site. The flat boulder containing panel 1 is in left foreground, panels 2 and 3 are on the boulder in center mid-ground, and the large main boulder with the rest of the panels is in the background. Photograph by author, 2016.

C.5 – View of the Mt. Rich site from the road next to the new viewing house that was erected to lessen tourist impact on the site by providing visitors means to see the rock art without having to climb down into the ravine. Through the thick tropical vegetation, only the main boulder is clearly visible. Photograph by author, 2016.

Appendix D:

Selected RASI sheets and photographs from Case Study #2

D.1 – Duquesne Bay Panel 2. Often inundated with run off and flooding, pools of standing water can be seen in the lower left corner. Numerous “bathtub rings” along the base and colored deposits running down the right side of the panel illustrate the significant impact water can have on rock art panels. Photograph taken by author, 2015.

D.2 – Front and back of student completed 2015 RASI score sheet for Duquesne Bay Panel 2. Student's name is obscured for their privacy.

Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)	near stagnet water basin pilling water on bottom	X			
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	looks like Fe but may be paint like panel #1

Other Notes:

Rock Art Stability Index

Your name:

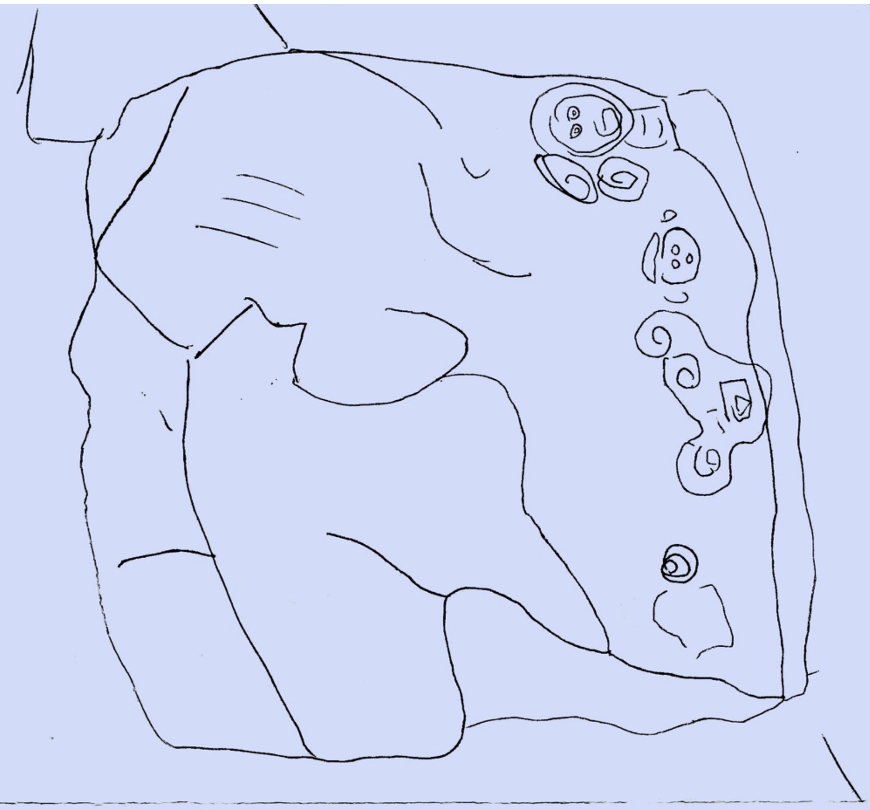
Date: May 25, 2015

Panel: #2

Panel Location: Duquesne Bay

Panel Aspect: 350°

Panel Sketch:



D.3 – Centerfold of student completed 2015 RASI score sheet for Duquesne Bay Panel 2.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three *can't* scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow) Stagnant water	0	1	2	3

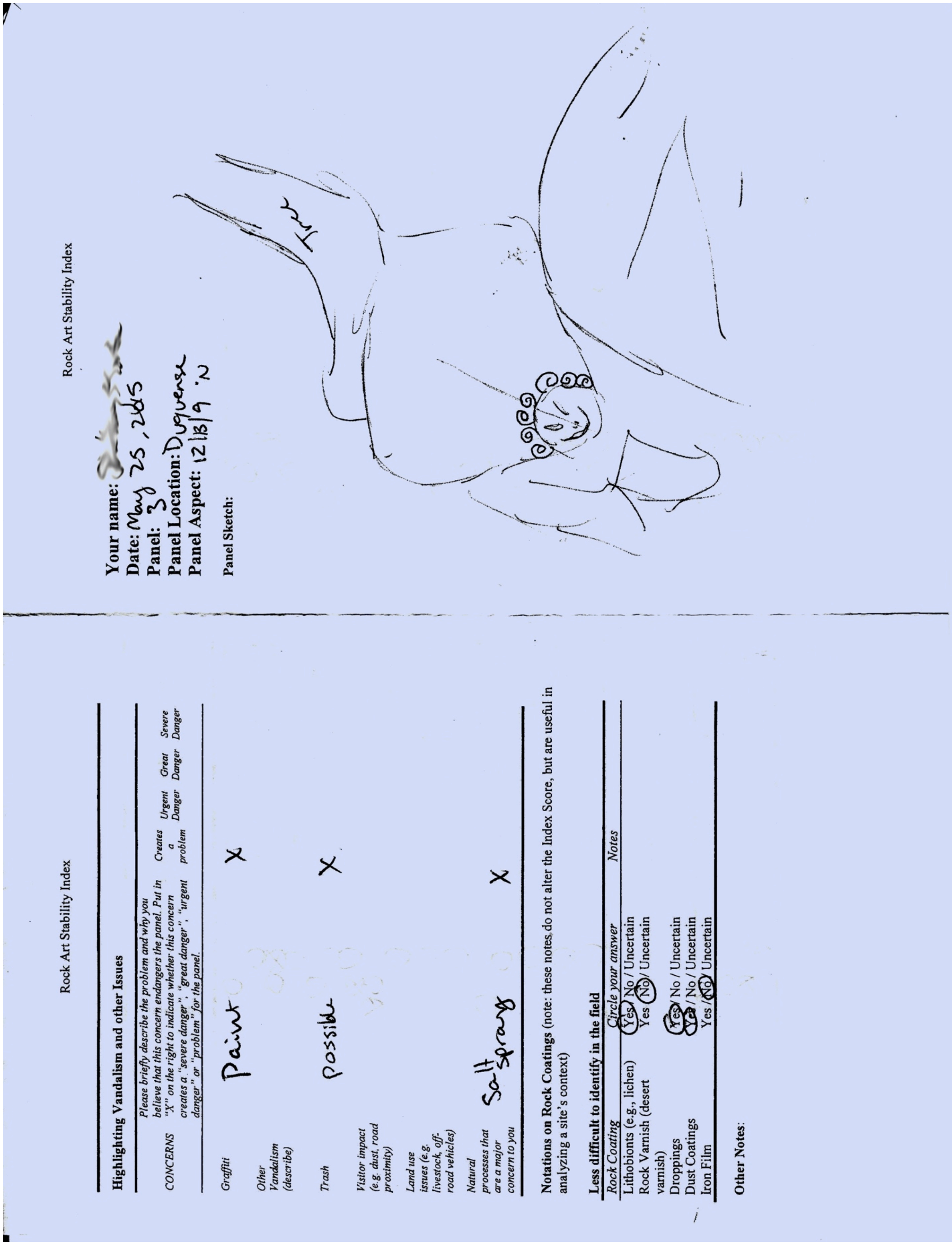
Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	-1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	-1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

D.4 – Duquesne Bay Panel 3. Bridging two sides of its host boulder and facing the ground, this panel is unique among the Grenadian petroglyphs. Photograph taken by author, 2015.

D.5 – Front and back of student completed 2015 RASI score sheet for Duquesne Bay Panel 3. Student's name is obscured for their privacy.



Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti	Paint	X			
Other Vandalism (describe)					
Trash	possible	X			
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you	Salt spray	X			

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Rock Art Stability Index

Your name:
Date: May 25, 2015
Panel: 3
Panel Location: Duquense
Panel Aspect: 12|13|9 °N

Panel Sketch:

D.6 – Centerfold of student completed 2015 RASI score sheet for Duquesne Bay Panel 3.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three *can't* scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow) sea spray	0	1	2	3

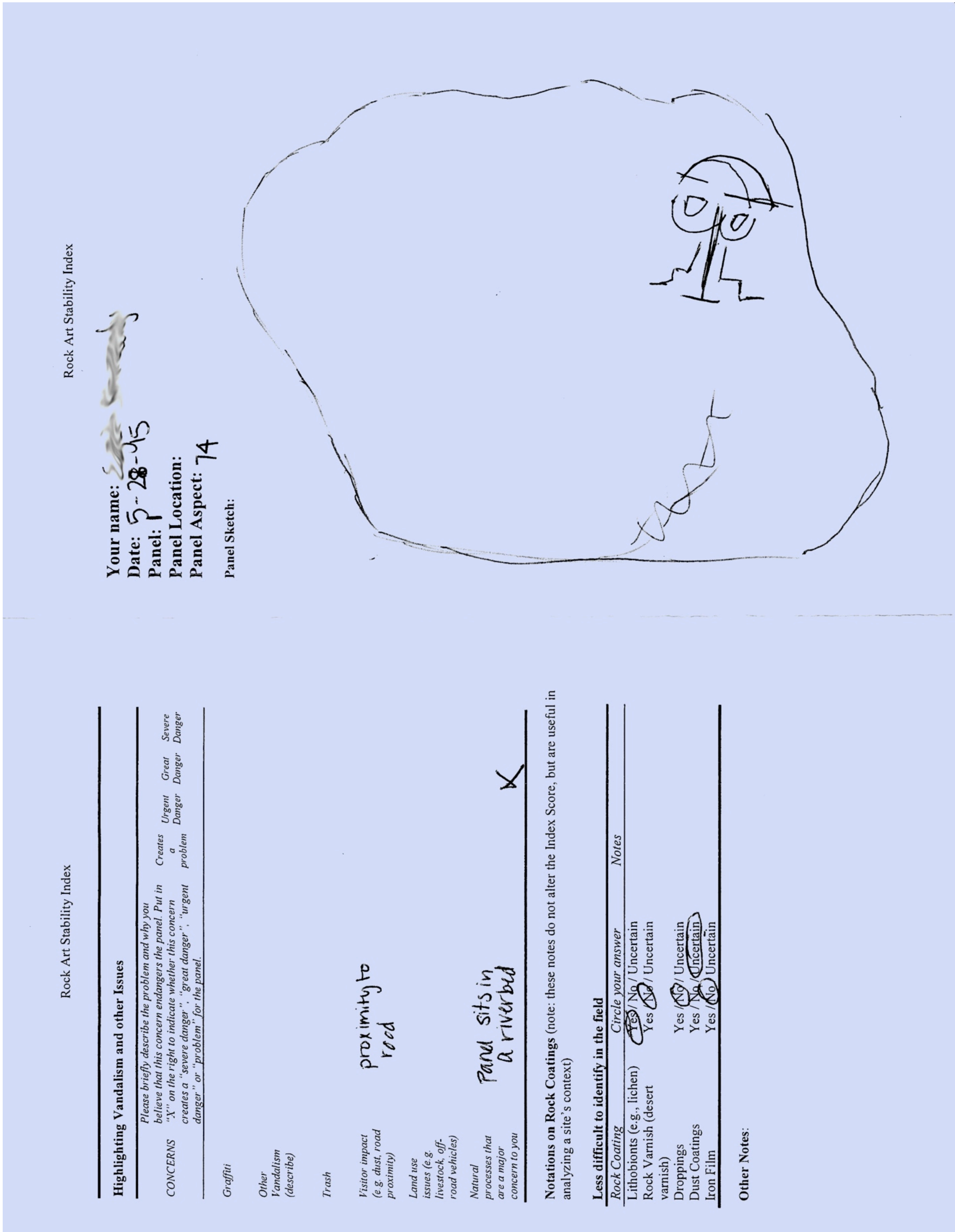
Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

D.7 – Mt. Rich Panel 1. Very faint, the lone petroglyph on panel one (upper right) can only be seen in certain light, when wet, or when filled with fine debris, as seen here. Photograph provided by C.D. Allen, 2012. The photograph is older than the assessment year but this panel was fairly unaffected by the 2015 cleaning as it is the farthest from the primary boulder housing most of the site's petroglyphs.

D.8 – Front and back of student completed 2015 RASI score sheet for Mt. Rich Panel 1. Student's name is obscured for their privacy.



Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)	proximity to road				
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you	Panel sits in a riverbed				X

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Rock Art Stability Index

Your name: [redacted]
Date: 5-28-15
Panel: 1
Panel Location:
Panel Aspect: 74

Panel Sketch:

D.9 – Centerfold of student completed 2015 RASI score sheet for Mt. Rich Panel 1.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three *can't* scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow) located in a river	0	1	2	3

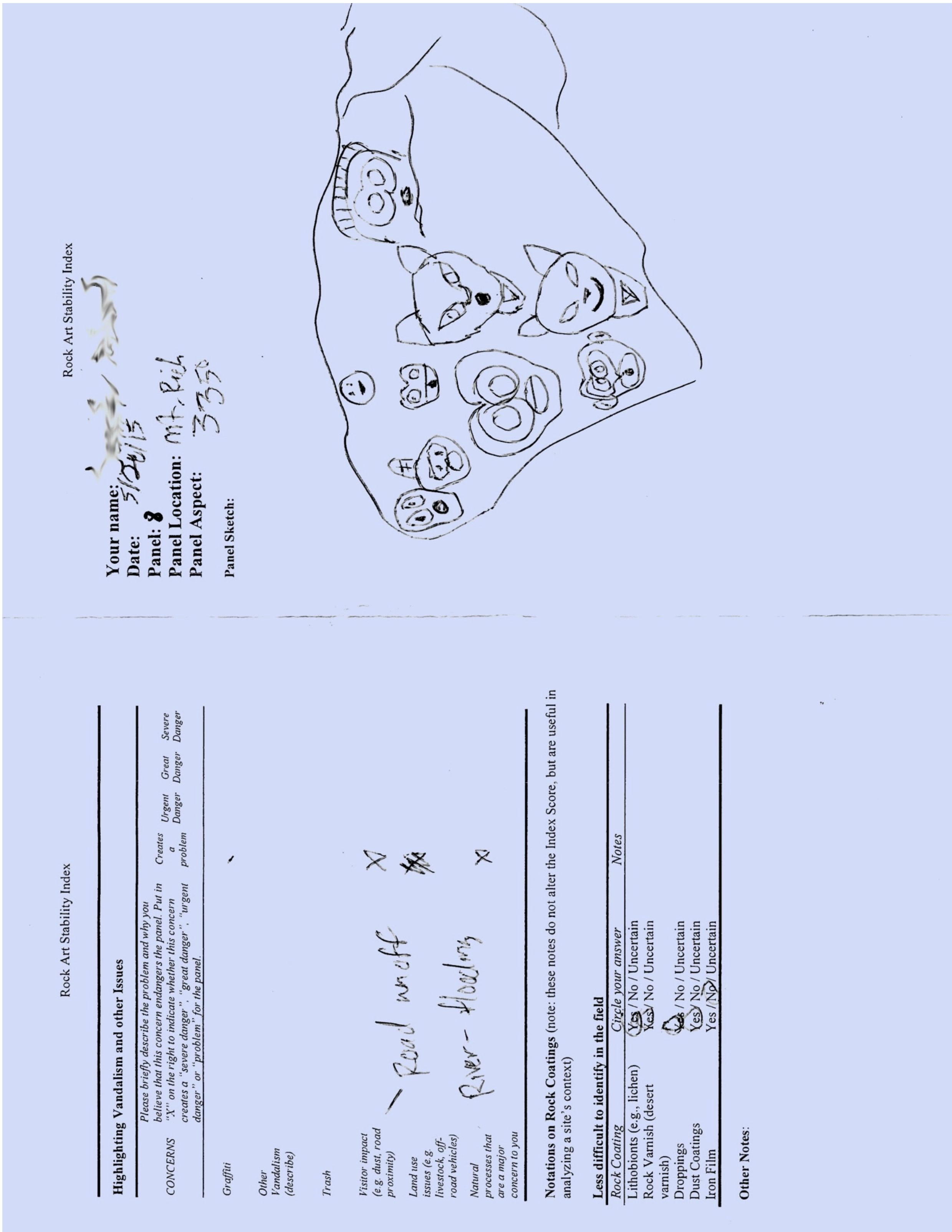
Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds) river beds & hanging trees	0	1	2	3

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	-1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	-1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

D.12 – Mt. Rich Panel 8 with the only known big cat motifs in the Lesser Antilles. Because the panel is located on the upstream side of the main boulder, little rock coating or lithobionts have grown on its surface. Photograph taken by author, 2015.

D.10 – Front and back of student completed 2015 RASI score sheet for Mt. Rich Panel 8. Student’s name is obscured for their privacy.



D.11 – Centerfold of student completed 2015 RASI score sheet for Mt. Rich Panel 8.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three *can't* scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow)	0	1	2	3

Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

Appendix E:

Yearly RASI element comparisons for Duquesne Bay

Appendix E.1 – all panels

Site ID/ Panel ID	Collection date	Raw Score	Final Score	Fissures independent of stone lithification	Fissures dependent on lithification
Duquesne Bay	2012	30	61	2.17	0.92
Panel 1	2013	31	61	2.14	0.43
	2015	30	59	2.30	0.22
	2016	30	59	2.50	0.00
	Mean:	30	60	2.28	0.39
	Trend:	0.43	1.00	0.14	0.34
	Var:	0.19	1.00	0.02	0.11
Duquesne Bay	2012	31	62	1.67	0.67
Panel 2	2013	31	62	1.89	0.00
	2015	31	61	2.20	0.20
	2016	30	60	2.50	0.00
	Mean:	31	61	2.06	0.22
	St. Dev:	0.43	0.83	0.32	0.27
	Var:	0.19	0.69	0.10	0.07
Duquesne Bay	2012	15	31	0.50	0.00
Panel 3	2013	15	30	0.44	0.00
	2015	19	37	1.00	0.13
	2016	20	39	0.00	0.00
	Mean:	17	34	0.49	0.03
	St. Dev:	2.28	3.83	0.35	0.05
	Var:	5.19	14.69	0.13	0.00
Duquesne Bay	2012		51	1.63	0.63
Site Average	2013		51	1.44	0.12
	2015		52	1.89	0.19
	2016		53	1.67	0.00
		Mean:	52	1.66	0.23
		St. Dev:	0.83	0.16	0.24
		Var:	0.69	0.03	0.06

Appendix E.1 (cont.)

Site ID/ Panel ID	Changes in textural anomalies	Rock weakness	Fissuresol	Roots	Plant growth near or on panel	Scaling & flaking
Duquesne Bay	0.42	2.00	1.58	0.08	0.08	1.58
Panel 1	1.43	1.71	1.29	0.14	0.71	0.86
	0.00	2.00	2.00	0.00	0.00	1.80
	1.00	2.00	1.00	0.00	0.50	1.50
	0.71	1.93	1.47	0.06	0.32	1.44
	0.55	0.12	0.37	0.06	0.29	0.35
	0.30	0.02	0.14	0.00	0.09	0.12
Duquesne Bay	0.67	2.00	0.83	0.17	0.83	1.17
Panel 2	0.56	1.67	1.56	0.33	0.22	1.89
	0.10	2.00	1.30	0.00	0.22	1.60
	1.50	2.00	1.50	0.00	0.50	1.50
	0.71	1.92	1.30	0.13	0.44	1.54
	0.51	0.14	0.28	0.14	0.25	0.26
	0.26	0.02	0.08	0.02	0.06	0.07
Duquesne Bay	0.00	2.00	0.00	0.17	0.00	0.67
Panel 3	0.22	2.00	0.33	0.67	0.78	0.11
	0.56	2.11	0.56	1.10	1.40	1.00
	0.50	2.00	0.50	0.50	1.00	0.50
	0.32	2.03	0.35	0.61	0.79	0.57
	0.22	0.05	0.22	0.34	0.51	0.32
	0.05	0.00	0.05	0.11	0.26	0.10
Duquesne Bay	0.38	2.00	1.00	0.13	0.25	1.25
Site Average	0.68	1.80	1.04	0.40	0.56	0.96
	0.21	2.03	1.31	0.37	0.55	1.47
	1.00	2.00	1.00	0.17	0.67	1.17
	0.57	1.96	1.09	0.26	0.51	1.21
	0.30	0.09	0.13	0.12	0.16	0.18
	0.09	0.01	0.02	0.01	0.02	0.03

Appendix E.1 (cont.)

Site ID/ Panel ID	Splintering	Undercutting	Weathering-rind development	Other concerns	Anthropogenic Activities
Duquesne Bay	0.58	1.00	0.50	1.83	0.17
Panel 1	0.14	0.57	1.14	2.29	0.86
	0.00	1.00	0.00	2.00	0.00
	0.00	0.50	0.50	2.50	0.00
	0.18	0.77	0.54	2.15	0.26
	0.24	0.23	0.41	0.26	0.35
	0.06	0.05	0.16	0.07	0.13
Duquesne Bay	0.50	1.00	0.67	1.67	0.00
Panel 2	1.00	1.44	1.11	1.78	0.33
	0.60	1.11	0.60	2.50	0.33
	0.00	0.50	1.50	2.50	0.00
	0.53	1.01	0.97	2.11	0.17
	0.36	0.34	0.36	0.39	0.17
	0.13	0.11	0.13	0.15	0.03
Duquesne Bay	0.17	0.50	0.17	1.17	0.00
Panel 3	0.11	1.44	0.44	0.67	0.22
	0.00	0.20	0.20	1.50	0.70
	0.00	1.50	0.00	2.00	0.00
	0.07	0.91	0.20	1.33	0.23
	0.07	0.57	0.16	0.49	0.29
	0.01	0.33	0.03	0.24	0.08
Duquesne Bay	0.46	0.88	0.46	1.63	0.08
Site Average	0.44	1.20	0.88	1.52	0.44
	0.21	0.76	0.27	2.00	0.36
	0.00	0.83	0.67	2.33	0.00
	0.28	0.92	0.57	1.87	0.22
	0.19	0.17	0.23	0.32	0.18
	0.04	0.03	0.05	0.10	0.03

Appendix E.1 (cont.)

Site ID/ Panel ID	Fissuresol/calcrete wedging	Fire	Undercutting	Other natural causes	Abrasion	Anthropogenic Cutting
Duquesne Bay	1.08	0.00	1.17	0.50	1.92	0.17
Panel 1	0.71	0.00	0.14	0.86	1.57	0.00
	0.00	0.00	1.50	0.00	2.00	0.00
	0.50	0.00	0.50	0.00	2.50	1.50
	0.57	0.00	0.83	0.34	2.00	0.42
	0.39	0.00	0.53	0.36	0.33	0.63
	0.15	0.00	0.29	0.13	0.11	0.40
Duquesne Bay	0.50	0.00	1.33	0.50	2.17	0.00
Panel 2	0.78	0.00	1.56	0.67	1.89	1.11
	0.70	0.00	1.70	0.56	1.89	0.00
	1.00	0.00	1.00	2.00	2.50	0.00
	0.74	0.00	1.40	0.93	2.11	0.28
	0.18	0.00	0.26	0.62	0.25	0.48
	0.03	0.00	0.07	0.38	0.06	0.23
Duquesne Bay	0.00	0.00	1.17	0.17	1.17	0.00
Panel 3	0.11	0.00	1.67	0.22	0.56	0.00
	0.40	0.00	0.10	0.40	1.10	0.00
	0.50	0.00	0.50	0.00	1.00	0.50
	0.25	0.00	0.86	0.20	0.96	0.13
	0.20	0.00	0.60	0.14	0.24	0.22
	0.04	0.00	0.36	0.02	0.06	0.05
Duquesne Bay	0.67	0.00	1.21	0.42	1.79	0.08
Site Average	0.52	0.00	1.20	0.56	1.32	0.40
	0.37	0.00	1.10	0.31	1.66	0.00
	0.67	0.00	0.67	0.67	2.00	0.67
	0.56	0.00	1.04	0.49	1.69	0.29
	0.12	0.00	0.22	0.14	0.25	0.26
	0.02	0.00	0.05	0.02	0.06	0.07

Appendix E.1 (cont.)

Site ID/ Panel ID	Alveolization	Crumbly disintegration	Flaking	Flaking of the weathering rind	Granular disintigration
Duquesne Bay	0.83	0.42	1.08	0.27	1.08
Panel 1	1.14	0.57	1.43	0.86	1.29
	1.40	1.40	1.10	0.00	0.80
	1.00	0.50	0.50	0.50	1.00
	1.09	0.72	1.03	0.41	1.04
	0.21	0.40	0.33	0.31	0.17
	0.04	0.16	0.11	0.10	0.03
Duquesne Bay	1.17	0.33	1.00	0.00	1.67
Panel 2	0.78	0.78	2.00	0.67	0.67
	1.40	0.80	1.50	0.40	1.40
	0.50	1.00	1.00	0.50	0.00
	0.96	0.73	1.38	0.39	0.93
	0.35	0.24	0.41	0.25	0.65
	0.12	0.06	0.17	0.06	0.42
Duquesne Bay	0.17	0.20	1.20	0.00	1.17
Panel 3	0.11	1.00	0.00	0.00	0.44
	0.40	0.33	0.89	0.00	0.50
	0.00	0.50	0.00	0.00	0.00
	0.17	0.51	0.52	0.00	0.53
	0.15	0.30	0.53	0.00	0.42
	0.02	0.09	0.28	0.00	0.17
Duquesne Bay	0.75	0.35	1.09	0.13	1.25
Site Average	0.64	0.80	1.12	0.48	0.76
	1.07	0.86	1.17	0.14	0.90
	0.50	0.67	0.50	0.33	0.33
	0.74	0.67	0.97	0.27	0.81
	0.21	0.20	0.27	0.15	0.33
	0.04	0.04	0.07	0.02	0.11

Appendix E.1 (cont.)

Site ID/ Panel ID	Lithobiont pitting	Lithobiont release	Loss parallel to stone structure	Rock coating detachment	Rounding of petroglyph edge
Duquesne Bay	1.58	0.58	0.50	1.25	1.83
Panel 1	1.43	0.86	1.14	1.14	2.14
	2.60	0.70	0.00	1.50	2.90
	1.00	1.50	0.00	1.50	2.50
	1.65	0.91	0.41	1.35	2.34
	0.59	0.35	0.47	0.16	0.40
	0.34	0.13	0.22	0.02	0.16
Duquesne Bay	1.83	0.83	0.83	1.17	1.83
Panel 2	1.44	0.78	0.33	1.00	2.11
	1.60	0.50	0.00	1.70	2.70
	0.50	1.50	0.00	1.00	1.50
	1.34	0.90	0.29	1.22	2.04
	0.51	0.37	0.34	0.29	0.44
	0.26	0.13	0.12	0.08	0.19
Duquesne Bay	1.17	0.00	0.00	0.50	2.33
Panel 3	0.00	0.00	0.00	0.56	1.67
	1.00	0.40	0.00	0.30	2.00
	1.00	1.00	0.00	1.00	2.50
	0.79	0.35	0.00	0.59	2.13
	0.46	0.41	0.00	0.26	0.32
	0.21	0.17	0.00	0.07	0.10
Duquesne Bay	1.54	0.50	0.46	1.04	1.96
Site Average	0.92	0.52	0.44	0.88	1.96
	1.73	0.53	0.00	1.17	2.53
	0.83	1.33	0.00	1.17	2.17
	1.26	0.72	0.22	1.06	2.15
	0.39	0.35	0.22	0.12	0.23
	0.15	0.12	0.05	0.01	0.05

Appendix E.1 (cont.)

Site ID/ Panel ID	Scaling	Textural anomaly features erode differently	Splintering	Other forms of incremental erosion	Anthropogenic	Rock coating present
Duquesne Bay	2.00	0.67	0.75	0.75	0.00	-1.25
Panel 1	1.00	0.71	0.29	0.71	0.43	-1.71
	1.00	0.40	0.00	1.56	1.50	-2.00
	1.50	1.00	0.00	2.50	0.00	-2.00
	1.38	0.70	0.26	1.38	0.48	-1.74
	0.41	0.21	0.31	0.73	0.61	0.31
	0.17	0.05	0.09	0.53	0.38	0.09
Duquesne Bay	1.67	0.83	0.50	0.83	0.00	-1.00
Panel 2	0.67	0.22	1.11	0.78	0.78	-1.78
	2.00	0.40	1.10	0.50	1.20	-2.20
	2.50	1.00	0.00	1.50	0.00	-2.50
	1.71	0.61	0.68	0.90	0.49	-1.87
	0.67	0.31	0.46	0.37	0.52	0.56
	0.45	0.10	0.21	0.13	0.27	0.32
Duquesne Bay	0.50	0.50	0.00	0.33	1.00	-1.67
Panel 3	0.00	0.78	0.00	0.44	1.00	-0.56
	0.10	0.20	0.30	0.50	1.50	-1.50
	0.50	1.00	0.00	0.50	1.50	-1.00
	0.28	0.62	0.08	0.44	1.25	-1.18
	0.23	0.30	0.13	0.07	0.25	0.44
	0.05	0.09	0.02	0.00	0.06	0.19
Duquesne Bay	1.54	0.67	0.50	0.67	0.25	-1.29
Site Average	0.52	0.56	0.48	0.64	0.76	-1.32
	1.03	0.33	0.47	0.85	1.40	-1.90
	1.50	1.00	0.00	1.50	0.50	-1.83
	1.15	0.64	0.36	0.91	0.73	-1.59
	0.41	0.24	0.21	0.35	0.43	0.28
	0.17	0.06	0.04	0.12	0.18	0.08

Appendix E.1 (cont.)

Site ID/ Panel ID	Case hardening	Salt efflorescence of subflorescence
Duquesne Bay	-0.75	1.08
Panel 1	-0.29	0.57
	0.00	0.00
	0.00	0.00
	-0.26	0.41
	0.31	0.45
	0.09	0.20
Duquesne Bay	-0.67	1.33
Panel 2	-1.33	0.33
	-1.67	-0.10
	-0.50	0.00
	-1.04	0.39
	0.48	0.57
	0.23	0.32
Duquesne Bay	-0.50	0.67
Panel 3	-0.33	0.00
	-0.30	0.20
	0.00	0.00
	-0.28	0.22
	0.18	0.27
	0.03	0.07
Duquesne Bay	-0.67	1.04
Site Average	-0.68	0.28
	-0.62	0.03
	-0.17	0.00
	-0.53	0.34
	0.21	0.42
	0.05	0.18

Appendix F:

Yearly RASI element comparisons for Mount Rich

F.1 – Panels 1-5

Site ID/ Panel ID	Collection date	Raw Score	Final Score	Fissures independent of stone lithification	Fissures dependent on lithification
Mount Rich	2012	24	47	0.50	0.00
Panel 1	2013	18	36	0.50	0.00
	2015	25	51	0.00	0.00
	2016	21	41	0.00	0.00
	Mean:	22	44	0.25	0.00
	St. Dev:	2.74	5.72	0.25	0.00
	Var:	7.50	32.69	0.06	0.00
Mount Rich	2012	21	42	1.25	0.50
Panel 2	2013	21	42	1.20	0.00
	2015	29	59	1.00	0.67
	2016	19	37	1.50	0.00
	Mean:	23	45	1.24	0.29
	St. Dev:	3.84	8.34	0.18	0.30
	Var:	14.75	69.50	0.03	0.09
Mount Rich	2012	27	54	1.75	1.00
Panel 3	2013	28	55	2.00	0.00
	2015	34	67	2.33	0.00
	2016	20	39	2.50	0.50
	Mean:	27	54	2.15	0.38
	St. Dev:	4.97	9.93	0.29	0.41
	Var:	24.69	98.69	0.08	0.17
Mount Rich	2012	24	47	1.75	0.25
Panel 4	2013	23	46	1.50	0.00
	2015	42	84	2.67	0.33
	2016	26	52	2.50	0.25
	Mean:	29	57	2.10	0.21
	St. Dev:	7.73	15.61	0.49	0.13
	Var:	59.69	243.69	0.24	0.02
Mount Rich	2012	18	36	1.50	0.25
Panel 5	2013	17	34	1.00	0.33
	2015	25	49	2.00	0.00
	2016	19	38	1.50	0.00
	Mean:	20	39	1.50	0.15
	St. Dev:	3.11	5.80	0.35	0.15
	Var:	9.69	33.69	0.13	0.02

Appendix F.1 (cont.)

Site ID/ Panel ID	Changes in textural anomalies	Rock weakness	Fissuresol	Roots	Plant growth near or on panel
Mount Rich	0.75	2.00	0.00	0.00	1.00
Panel 1	1.25	2.00	0.00	0.00	0.50
	1.00	2.00	0.00	0.00	1.00
	1.50	2.00	0.00	0.00	0.50
	1.13	2.00	0.00	0.00	0.75
	0.28	0.00	0.00	0.00	0.25
	0.08	0.00	0.00	0.00	0.06
Mount Rich	0.25	2.00	0.50	0.00	0.75
Panel 2	0.40	2.00	1.80	0.20	1.40
	1.67	1.67	1.00	0.33	1.33
	1.50	2.00	0.00	1.00	2.50
	0.95	1.92	0.83	0.38	1.50
	0.63	0.14	0.66	0.38	0.63
	0.40	0.02	0.44	0.14	0.40
Mount Rich	0.50	2.00	1.00	0.00	0.75
Panel 3	0.00	2.00	1.50	1.00	2.00
	2.33	1.33	2.00	0.33	2.00
	1.50	2.00	0.50	0.50	1.50
	1.08	1.83	1.25	0.46	1.56
	0.90	0.29	0.56	0.36	0.51
	0.81	0.08	0.31	0.13	0.26
Mount Rich	0.25	2.00	0.86	0.29	1.25
Panel 4	0.50	2.00	1.00	0.50	1.50
	1.50	0.67	1.80	0.17	0.83
	1.25	2.00	0.50	0.50	0.75
	0.88	1.67	1.04	0.36	1.08
	0.52	0.58	0.48	0.14	0.31
	0.27	0.33	0.23	0.02	0.09
Mount Rich	0.50	2.00	0.00	0.00	0.00
Panel 5	0.67	2.00	0.67	0.00	1.00
	0.67	1.00	0.33	0.33	1.33
	1.00	2.00	0.50	0.00	1.00
	0.71	1.75	0.38	0.08	0.83
	0.18	0.43	0.25	0.14	0.50
	0.03	0.19	0.06	0.02	0.25

Appendix F.1 (cont.)

Site ID/ Panel ID	Scaling & flaking	Splintering	Undercutting	Weathering-rind development	Other concerns
Mount Rich	0.50	0.00	1.00	0.50	2.50
Panel 1	0.00	0.00	0.00	0.25	1.50
	0.33	0.00	1.00	0.33	3.00
	0.00	0.00	0.50	2.50	3.00
	0.21	0.00	0.63	0.90	2.50
	0.22	0.00	0.41	0.93	0.61
	0.05	0.00	0.17	0.87	0.38
Mount Rich	0.00	0.25	1.00	0.75	1.25
Panel 2	1.20	0.00	0.80	0.80	0.60
	1.33	0.33	1.00	0.00	2.33
	0.00	0.00	0.00	2.00	2.50
	0.63	0.15	0.70	0.89	1.67
	0.64	0.15	0.41	0.72	0.78
	0.40	0.02	0.17	0.51	0.61
Mount Rich	0.75	0.00	1.25	0.33	1.75
Panel 3	1.00	0.00	0.00	1.00	0.00
	1.33	0.00	1.00	0.00	1.33
	0.50	0.00	1.50	0.50	2.50
	0.90	0.00	0.94	0.46	1.40
	0.31	0.00	0.57	0.36	0.91
	0.10	0.00	0.32	0.13	0.82
Mount Rich	0.88	0.00	1.25	0.88	0.71
Panel 4	0.63	0.00	1.38	0.38	0.63
	1.50	0.83	2.83	0.00	1.00
	1.00	0.00	2.00	2.00	2.50
	1.00	0.21	1.86	0.81	1.21
	0.32	0.36	0.63	0.75	0.76
	0.10	0.13	0.39	0.57	0.57
Mount Rich	1.25	0.00	1.00	0.50	0.50
Panel 5	1.00	0.00	0.33	0.00	0.00
	0.33	0.00	1.00	0.00	1.67
	0.50	0.00	1.00	2.00	0.50
	0.77	0.00	0.83	0.63	0.67
	0.37	0.00	0.29	0.82	0.61
	0.14	0.00	0.08	0.67	0.38

Appendix F.1 (cont.)

Site ID/ Panel ID	Anthropogenic Activities	Fissuresol/calcrete wedging	Fire	Undercutting	Other natural causes	Abrasion
Mount Rich	0.00	0.50	0.00	1.00	1.00	2.00
Panel 1	0.00	0.00	0.00	0.00	0.00	2.50
	1.00	0.33	0.00	1.33	0.67	2.00
	0.00	0.00	0.00	0.00	0.00	1.50
	0.25	0.21	0.00	0.58	0.42	2.00
	0.43	0.22	0.00	0.60	0.43	0.35
	0.19	0.05	0.00	0.35	0.19	0.13
Mount Rich	0.00	1.25	0.00	1.00	0.25	1.75
Panel 2	0.00	0.80	0.20	0.00	0.40	0.60
	0.33	0.67	0.00	1.67	0.33	1.33
	0.00	0.00	0.00	0.00	0.50	1.00
	0.08	0.68	0.05	0.67	0.37	1.17
	0.14	0.45	0.09	0.71	0.09	0.42
	0.02	0.20	0.01	0.50	0.01	0.18
Mount Rich	0.00	0.75	0.00	1.50	0.75	1.50
Panel 3	0.00	0.00	0.00	0.00	0.00	1.50
	0.00	1.33	0.00	1.33	0.00	3.00
	0.00	0.00	0.00	1.00	1.50	0.50
	0.00	0.52	0.00	0.96	0.56	1.63
	0.00	0.56	0.00	0.58	0.62	0.89
	0.00	0.31	0.00	0.34	0.39	0.80
Mount Rich	0.00	0.38	0.00	1.13	0.75	1.38
Panel 4	0.00	0.75	0.00	0.38	1.50	0.63
	1.83	1.17	0.00	2.50	0.00	2.50
	0.00	0.00	0.00	1.50	1.00	0.00
	0.46	0.57	0.00	1.38	0.81	1.13
	0.79	0.43	0.00	0.77	0.54	0.93
	0.63	0.19	0.00	0.59	0.29	0.87
Mount Rich	0.00	0.00	0.00	1.00	0.50	0.75
Panel 5	0.00	0.33	0.00	0.67	0.00	0.33
	0.00	0.33	0.00	0.67	0.00	2.33
	0.00	0.50	0.00	1.00	0.00	0.50
	0.00	0.29	0.00	0.83	0.13	0.98
	0.00	0.18	0.00	0.17	0.22	0.80
	0.00	0.03	0.00	0.03	0.05	0.63

Appendix F.1 (cont.)

Site ID/ Panel ID	Anthropogenic Cutting	Alveolization	Crumbly disintegration	Flaking	Flaking of the weathering rind
Mount Rich	0.00	1.00	0.50	0.25	0.25
Panel 1	0.00	0.00	0.50	0.25	0.00
	0.33	1.00	0.00	0.33	0.33
	0.00	0.00	0.00	0.00	0.50
	0.08	0.50	0.25	0.21	0.27
	0.14	0.50	0.25	0.13	0.18
	0.02	0.25	0.06	0.02	0.03
Mount Rich	0.00	1.00	0.50	0.50	0.00
Panel 2	0.00	0.00	0.00	0.20	0.20
	0.00	1.33	0.33	1.33	0.00
	0.00	0.50	0.00	0.00	0.00
	0.00	0.71	0.21	0.51	0.05
	0.00	0.51	0.22	0.51	0.09
	0.00	0.26	0.05	0.26	0.01
Mount Rich	0.00	1.25	1.00	0.50	0.00
Panel 3	0.00	0.00	0.00	0.00	0.00
	0.00	1.67	1.00	0.67	0.00
	0.00	0.00	0.00	0.00	0.00
	0.00	0.73	0.50	0.29	0.00
	0.00	0.74	0.50	0.30	0.00
	0.00	0.55	0.25	0.09	0.00
Mount Rich	0.00	0.63	0.57	0.63	0.50
Panel 4	0.00	0.50	0.00	0.38	0.13
	0.83	2.17	1.00	1.17	0.00
	0.00	0.25	0.00	0.25	0.25
	0.21	0.89	0.39	0.60	0.22
	0.36	0.75	0.42	0.35	0.18
	0.13	0.57	0.18	0.12	0.03
Mount Rich	0.00	0.25	0.25	0.75	0.00
Panel 5	0.00	0.00	1.00	0.50	0.50
	1.00	1.67	0.33	0.67	0.00
	0.00	0.50	0.00	0.50	0.50
	0.25	0.60	0.40	0.60	0.25
	0.43	0.64	0.37	0.11	0.25
	0.19	0.41	0.14	0.01	0.06

Appendix F.1 (cont.)

Site ID/ Panel ID	Granular disintigration	Lithobiont pitting	Lithobiont release	Loss parallel to stone structure	Rock coating detachment
Mount Rich	1.25	1.00	0.75	0.75	0.50
Panel 1	0.25	1.75	0.25	0.00	1.50
	0.33	3.00	0.00	0.33	1.00
	0.00	2.50	2.00	0.00	1.00
	0.46	2.06	0.75	0.27	1.00
	0.47	0.76	0.77	0.31	0.35
	0.22	0.57	0.59	0.10	0.13
Mount Rich	0.75	1.50	0.50	0.00	0.75
Panel 2	0.80	1.00	0.00	0.20	0.00
	0.67	2.00	0.33	0.00	1.00
	0.00	2.00	1.50	0.00	0.00
	0.55	1.63	0.58	0.05	0.44
	0.32	0.41	0.56	0.09	0.45
	0.10	0.17	0.31	0.01	0.20
Mount Rich	0.75	2.00	1.25	0.25	0.75
Panel 3	1.00	2.00	0.00	0.00	1.00
	0.67	2.33	0.33	0.33	0.67
	0.00	2.00	1.00	0.00	0.50
	0.60	2.08	0.65	0.15	0.73
	0.37	0.14	0.50	0.15	0.18
	0.14	0.02	0.25	0.02	0.03
Mount Rich	0.75	1.75	1.00	0.50	0.63
Panel 4	0.63	1.25	0.88	0.00	0.00
	0.67	2.67	1.00	0.33	1.17
	0.00	1.75	0.75	0.00	0.75
	0.51	1.85	0.91	0.21	0.64
	0.30	0.51	0.10	0.22	0.42
	0.09	0.26	0.01	0.05	0.17
Mount Rich	0.75	1.75	1.00	0.25	0.00
Panel 5	0.50	1.33	0.33	0.33	0.67
	0.33	2.00	0.33	0.00	0.50
	0.00	1.50	1.00	0.00	0.50
	0.40	1.65	0.67	0.15	0.42
	0.27	0.25	0.33	0.15	0.25
	0.07	0.06	0.11	0.02	0.06

Appendix F.1 (cont.)

Site ID/ Panel ID	Rounding of petroglyph edge	Scaling	Textural anomaly features erode differently	Splintering	Other forms of incremental erosion
Mount Rich	2.75	0.75	1.25	0.00	0.50
Panel 1	3.00	0.00	0.50	0.00	0.50
	3.00	0.33	2.00	0.00	2.00
	3.00	0.00	1.50	0.00	1.00
	2.94	0.27	1.31	0.00	1.00
	0.11	0.31	0.54	0.00	0.61
	0.01	0.10	0.29	0.00	0.38
Mount Rich	2.25	0.50	0.75	0.25	0.25
Panel 2	2.00	0.20	0.60	0.20	0.60
	2.33	0.67	2.33	0.33	1.00
	2.50	0.00	1.00	0.00	0.50
	2.27	0.34	1.17	0.20	0.59
	0.18	0.26	0.69	0.12	0.27
	0.03	0.07	0.47	0.02	0.07
Mount Rich	2.25	1.00	0.50	0.25	0.50
Panel 3	2.00	1.50	0.00	0.00	0.00
	3.00	1.00	2.33	0.00	0.67
	3.00	0.50	1.00	0.00	2.00
	2.56	1.00	0.96	0.06	0.79
	0.45	0.35	0.87	0.11	0.74
	0.20	0.13	0.76	0.01	0.55
Mount Rich	2.25	0.88	0.25	0.00	0.63
Panel 4	2.13	1.50	1.63	0.00	0.50
	2.83	1.50	1.67	0.83	1.00
	3.00	0.50	1.00	0.00	2.25
	2.55	1.09	1.14	0.21	1.09
	0.37	0.43	0.58	0.36	0.69
	0.14	0.18	0.33	0.13	0.48
Mount Rich	1.50	1.25	1.25	0.00	0.25
Panel 5	0.67	0.33	0.67	0.00	0.67
	1.67	1.33	1.00	0.00	2.00
	2.00	0.50	1.00	0.00	1.50
	1.46	0.85	0.98	0.00	1.10
	0.49	0.44	0.21	0.00	0.69
	0.24	0.20	0.04	0.00	0.47

Appendix F.1 (cont.)

Site ID/ Panel ID	Anthropogenic	Rock coating present	Case hardening	Salt efflorescence of subflorescence
Mount Rich	0.00	-1.50	-0.50	0.75
Panel 1	0.00	-0.50	-0.25	0.00
	0.00	-2.33	-0.33	0.00
	0.00	-2.50	0.00	0.00
	0.00	-1.71	-0.27	0.19
	0.00	0.79	0.18	0.32
	0.00	0.63	0.03	0.11
Mount Rich	0.00	-1.00	-0.50	0.25
Panel 2	0.00	-1.40	-0.80	0.00
	0.00	-1.33	0.00	0.00
	0.00	-2.50	0.00	0.00
	0.00	-1.56	-0.33	0.06
	0.00	0.56	0.34	0.11
	0.00	0.32	0.12	0.01
Mount Rich	0.00	-1.00	-0.75	0.75
Panel 3	0.00	-1.00	0.00	0.00
	0.00	-1.00	0.00	0.00
	0.00	-2.50	0.00	0.00
	0.00	-1.38	-0.19	0.19
	0.00	0.65	0.32	0.32
	0.00	0.42	0.11	0.11
Mount Rich	0.00	-0.75	-0.38	0.00
Panel 4	0.00	-2.00	0.00	0.00
	1.00	-0.17	0.00	0.00
	0.00	-2.50	0.00	0.00
	0.25	-1.35	-0.09	0.00
	0.43	0.94	0.16	0.00
	0.19	0.88	0.03	0.00
Mount Rich	0.00	-1.00	-0.25	0.00
Panel 5	0.00	-0.67	-1.33	0.00
	0.00	0.00	0.00	0.00
	0.00	-2.50	0.00	0.00
	0.00	-1.04	-0.40	0.00
	0.00	0.92	0.55	0.00
	0.00	0.84	0.30	0.00

F.2 – Panels 6-9

Site ID/ Panel ID	Collection date	Raw Score	Final Score	Fissures independent of stone lithification	Fissures dependent on lithification
Mount Rich	2012	15	30	1.25	0.00
Panel 6	2013	15	29	0.33	0.00
	2015	23	46	1.33	0.33
	2016	26	51	2.50	0.00
	Mean:	20	39	1.35	0.08
	St. Dev:	4.87	9.67	0.77	0.14
	Var:	23.69	93.50	0.59	0.02
Mount Rich	2012	14	27	0.75	0.00
Panel 7	2013	15	29	0.67	0.00
	2015	24	49	1.00	0.33
	2016	18	36	0.00	0.00
	Mean:	18	35	0.60	0.08
	St. Dev:	3.90	8.61	0.37	0.14
	Var:	15.19	74.19	0.14	0.02
Mount Rich	2012	20	40	1.50	0.00
Panel 8	2013	21	42	2.00	0.00
	2015	41	81	3.17	0.33
	2016	23	45	2.00	0.50
	Mean:	26	52	2.17	0.21
	St. Dev:	8.58	16.84	0.61	0.22
	Var:	73.69	283.50	0.37	0.05
Mount Rich	2012	17	34	2.00	0.25
Panel 9	2013	18	36	2.00	0.00
	2015	34	68	2.67	1.00
	2016	23	45	1.75	0.75
	Mean:	23	46	2.10	0.50
	St. Dev:	6.75	13.50	0.34	0.40
	Var:	45.50	182.19	0.12	0.16
Mount Rich	2012		39	1.39	0.26
Site Average	2013		40	1.16	0.03
	2015		63	1.86	0.36
	2016		43	1.59	0.23
	Mean:		46	1.50	0.22
	St. Dev:		9.78	0.26	0.12
	Var:		95.69	0.07	0.01

Appendix F.2 (cont.)

Site ID/ Panel ID	Changes in textural anomalies	Rock weakness	Fissuresol	Roots	Plant growth near or on panel
Mount Rich	0.25	2.00	0.33	0.00	0.50
Panel 6	0.67	2.00	0.33	0.00	1.00
	0.33	1.67	0.67	0.33	1.00
	1.50	2.00	1.00	0.00	1.00
	0.69	1.92	0.58	0.08	0.88
	0.49	0.14	0.28	0.14	0.22
	0.24	0.02	0.08	0.02	0.05
Mount Rich	0.00	2.00	0.50	0.25	0.50
Panel 7	1.67	1.67	1.67	0.67	0.00
	0.67	2.00	0.67	0.33	1.33
	2.00	2.00	0.00	0.00	1.00
	1.08	1.92	0.71	0.31	0.71
	0.79	0.14	0.61	0.24	0.51
	0.63	0.02	0.37	0.06	0.26
Mount Rich	0.50	2.00	1.50	0.00	0.00
Panel 8	1.50	2.00	2.00	0.00	1.00
	1.50	3.00	2.67	0.17	1.50
	1.00	2.00	0.00	0.00	1.50
	1.13	2.25	1.54	0.04	1.00
	0.41	0.43	0.98	0.07	0.61
	0.17	0.19	0.96	0.01	0.38
Mount Rich	0.50	2.00	1.00	0.00	0.50
Panel 9	0.00	2.00	1.00	0.00	1.00
	1.33	1.67	2.00	0.00	1.00
	1.50	2.00	0.00	0.00	0.50
	0.83	1.92	1.00	0.00	0.75
	0.61	0.14	0.71	0.00	0.25
	0.38	0.02	0.50	0.00	0.06
Mount Rich	0.37	2.00	0.61	0.08	0.68
Site Average	0.74	1.97	1.06	0.29	1.10
	1.19	1.53	1.29	0.19	1.14
	1.41	2.00	0.23	0.23	1.14
	0.93	1.87	0.80	0.20	1.01
	0.40	0.20	0.41	0.08	0.19
	0.16	0.04	0.17	0.01	0.04

Appendix F.2 (cont.)

Site ID/ Panel ID	Scaling & flaking	Splintering	Undercutting	Weathering-rind development	Other concerns
Mount Rich	1.00	0.00	0.25	0.00	0.75
Panel 6	1.33	0.00	0.33	1.00	0.00
	1.33	0.33	0.33	0.33	0.67
	1.00	0.00	0.00	2.50	0.50
	1.17	0.08	0.23	0.96	0.48
	0.17	0.14	0.14	0.96	0.29
	0.03	0.02	0.02	0.92	0.08
Mount Rich	1.00	0.00	0.50	0.00	0.00
Panel 7	0.50	0.00	0.00	0.67	0.00
	1.33	0.33	0.00	0.33	1.00
	0.00	0.00	1.00	0.50	0.50
	0.71	0.08	0.38	0.38	0.38
	0.51	0.14	0.41	0.25	0.41
	0.26	0.02	0.17	0.06	0.17
Mount Rich	1.50	0.50	0.50	0.50	1.00
Panel 8	1.50	0.00	0.50	0.00	0.50
	2.17	1.00	0.67	0.50	2.00
	0.50	0.00	1.50	2.00	2.00
	1.42	0.38	0.79	0.75	1.38
	0.60	0.41	0.41	0.75	0.65
	0.35	0.17	0.17	0.56	0.42
Mount Rich	0.50	0.00	0.00	0.00	0.25
Panel 9	1.00	0.00	0.00	1.00	0.00
	1.50	0.50	1.33	0.00	1.17
	0.75	0.00	0.75	0.50	1.25
	0.94	0.13	0.52	0.38	0.67
	0.37	0.22	0.56	0.41	0.55
	0.14	0.05	0.31	0.17	0.30
Mount Rich	0.79	0.05	0.82	0.43	0.95
Site Average	0.83	0.00	0.58	0.52	0.48
	1.25	0.42	1.14	0.14	1.42
	0.50	0.00	0.86	1.55	1.73
	0.84	0.12	0.85	0.66	1.14
	0.27	0.17	0.20	0.53	0.47
	0.07	0.03	0.04	0.28	0.22

Appendix F.2 (cont.)

Site ID/ Panel ID	Anthropogenic Activities	Fissuresol/calcrete wedging	Fire	Undercutting	Other natural causes	Abrasion
Mount Rich	0.00	0.00	0.75	0.25	0.00	0.50
Panel 6	0.00	0.00	0.00	0.33	0.33	1.33
	0.33	1.00	0.00	1.00	0.00	1.00
	0.00	0.00	0.00	1.50	0.00	1.00
	0.08	0.25	0.19	0.77	0.08	0.96
	0.14	0.43	0.32	0.51	0.14	0.30
	0.02	0.19	0.11	0.26	0.02	0.09
Mount Rich	0.25	0.25	0.00	0.25	0.00	0.75
Panel 7	0.00	0.67	0.00	0.00	0.00	0.67
	0.00	0.67	0.00	0.00	0.00	0.67
	0.00	0.00	0.00	1.00	0.50	0.00
	0.06	0.40	0.00	0.31	0.13	0.52
	0.11	0.28	0.00	0.41	0.22	0.30
	0.01	0.08	0.00	0.17	0.05	0.09
Mount Rich	0.00	0.50	0.00	1.00	0.50	1.00
Panel 8	0.00	1.00	0.00	0.50	0.00	0.00
	0.17	1.17	0.00	0.83	0.17	1.67
	0.00	0.00	0.00	1.50	1.00	0.50
	0.04	0.67	0.00	0.96	0.42	0.79
	0.07	0.46	0.00	0.36	0.38	0.62
	0.01	0.21	0.00	0.13	0.15	0.38
Mount Rich	0.25	0.50	0.00	0.00	0.00	0.50
Panel 9	0.00	0.00	0.00	0.00	1.00	1.00
	1.50	1.33	0.00	0.83	0.83	2.17
	0.00	0.00	0.00	0.75	0.50	1.75
	0.44	0.46	0.00	0.40	0.58	1.35
	0.62	0.54	0.00	0.40	0.38	0.65
	0.39	0.30	0.00	0.16	0.15	0.42
Mount Rich	0.05	0.45	0.08	0.82	0.45	1.16
Site Average	0.00	0.48	0.03	0.23	0.52	0.94
	0.72	0.89	0.00	1.14	0.25	1.86
	0.00	0.05	0.00	0.86	0.55	0.82
	0.19	0.47	0.03	0.76	0.44	1.19
	0.31	0.30	0.03	0.33	0.12	0.40
	0.09	0.09	0.00	0.11	0.01	0.16

Appendix F.2 (cont.)

Site ID/ Panel ID	Anthropogenic Cutting	Alveolization	Crumbly disintegration	Flaking	Flaking of the weathering rind
Mount Rich	0.00	0.50	0.50	1.00	0.00
Panel 6	0.33	1.33	0.00	1.67	0.00
	0.33	2.00	0.33	1.33	0.67
	1.00	1.00	0.00	0.50	1.00
	0.42	1.21	0.21	1.13	0.42
	0.36	0.54	0.22	0.43	0.43
	0.13	0.30	0.05	0.19	0.19
Mount Rich	0.00	0.67	0.50	0.75	0.25
Panel 7	0.00	0.00	0.33	1.00	0.00
	0.00	2.00	0.33	2.33	0.67
	0.00	1.50	0.50	0.00	0.00
	0.00	1.04	0.42	1.02	0.23
	0.00	0.77	0.08	0.84	0.27
	0.00	0.59	0.01	0.71	0.07
Mount Rich	0.00	0.50	0.00	1.00	0.50
Panel 8	0.00	0.50	1.00	0.00	0.00
	0.17	1.83	0.33	2.17	0.50
	0.00	1.00	0.00	0.00	1.00
	0.04	0.96	0.33	0.79	0.50
	0.07	0.54	0.41	0.89	0.35
	0.01	0.30	0.17	0.80	0.13
Mount Rich	0.00	0.75	0.25	0.50	0.00
Panel 9	0.00	1.00	0.00	2.00	0.00
	1.17	2.17	0.33	0.67	0.00
	0.00	1.25	0.25	0.00	0.25
	0.29	1.29	0.21	0.79	0.06
	0.51	0.54	0.13	0.74	0.11
	0.26	0.29	0.02	0.55	0.01
Mount Rich	0.00	0.73	0.49	0.62	0.18
Site Average	0.03	0.32	0.26	0.53	0.10
	0.50	1.72	0.46	1.11	0.19
	0.09	0.68	0.09	0.14	0.36
	0.16	0.86	0.32	0.60	0.21
	0.20	0.52	0.16	0.35	0.10
	0.04	0.27	0.03	0.12	0.01

Appendix F.2 (cont.)

Site ID/ Panel ID	Granular disintigration	Lithobiont pitting	Lithobiont release	Loss parallel to stone structure	Rock coating detachment
Mount Rich	0.75	2.50	0.25	0.25	0.00
Panel 6	0.00	2.33	0.33	0.00	0.33
	0.33	2.00	0.67	0.00	0.33
	1.00	0.50	0.50	0.00	1.50
	0.52	1.83	0.44	0.06	0.54
	0.38	0.79	0.16	0.11	0.57
	0.15	0.63	0.03	0.01	0.32
Mount Rich	0.75	2.25	0.00	0.25	0.25
Panel 7	0.67	2.33	0.00	0.00	0.67
	1.00	2.33	0.50	0.00	0.33
	0.00	1.50	1.50	0.00	1.50
	0.60	2.10	0.50	0.06	0.69
	0.37	0.35	0.61	0.11	0.49
	0.14	0.12	0.38	0.01	0.24
Mount Rich	1.00	2.00	0.50	0.50	0.50
Panel 8	1.50	1.50	0.00	0.00	1.00
	0.83	3.50	1.50	0.00	1.33
	0.00	1.50	1.50	0.00	1.50
	0.83	2.13	0.88	0.13	1.08
	0.54	0.82	0.65	0.22	0.38
	0.29	0.67	0.42	0.05	0.15
Mount Rich	1.50	2.00	0.50	0.00	0.25
Panel 9	0.00	2.00	1.00	0.00	1.00
	1.50	2.67	0.67	0.50	1.17
	0.25	1.50	1.25	0.00	1.50
	0.81	2.04	0.85	0.13	0.98
	0.69	0.41	0.29	0.22	0.46
	0.48	0.17	0.08	0.05	0.21
Mount Rich	0.89	1.84	0.68	0.32	0.42
Site Average	0.60	1.58	0.35	0.06	0.52
	0.72	2.42	0.63	0.19	0.89
	0.14	1.64	1.18	0.00	0.95
	0.59	1.87	0.71	0.14	0.69
	0.28	0.33	0.30	0.12	0.23
	0.08	0.11	0.09	0.01	0.05

Appendix F.2 (cont.)

Site ID/ Panel ID	Rounding of petroglyph edge	Scaling	Textural anomaly features erode differently	Splintering	Other forms of incremental erosion
Mount Rich	2.50	0.75	0.00	0.00	0.25
Panel 6	1.00	0.00	0.67	0.00	0.33
	2.00	1.33	0.33	0.33	0.67
	2.50	0.50	2.00	0.00	1.50
	2.00	0.65	0.75	0.08	0.69
	0.61	0.48	0.76	0.14	0.49
	0.38	0.23	0.58	0.02	0.24
Mount Rich	1.75	1.00	0.00	0.00	0.00
Panel 7	1.33	0.33	1.00	0.00	0.00
	2.00	1.67	0.67	0.33	0.67
	3.00	0.00	1.50	0.00	1.00
	2.02	0.75	0.79	0.08	0.42
	0.61	0.64	0.54	0.14	0.43
	0.38	0.41	0.30	0.02	0.19
Mount Rich	1.00	1.50	0.50	0.00	0.00
Panel 8	1.50	0.50	1.00	0.00	0.00
	4.17	2.17	1.50	0.50	0.00
	2.00	0.50	1.50	0.00	1.50
	2.17	1.17	1.13	0.13	0.38
	1.21	0.71	0.41	0.22	0.65
	1.46	0.50	0.17	0.05	0.42
Mount Rich	2.25	0.50	0.67	0.00	0.50
Panel 9	2.00	1.00	1.00	0.00	0.00
	2.00	1.17	1.50	0.00	0.83
	2.00	0.50	1.50	0.00	1.25
	2.06	0.79	1.17	0.00	0.65
	0.11	0.30	0.35	0.00	0.46
	0.01	0.09	0.13	0.00	0.21
Mount Rich	2.13	0.87	0.54	0.05	0.37
Site Average	1.84	0.65	0.90	0.03	0.39
	2.42	1.22	1.42	0.28	0.89
	2.50	0.32	1.32	0.00	1.36
	2.22	0.76	1.04	0.09	0.75
	0.26	0.33	0.35	0.11	0.41
	0.07	0.11	0.12	0.01	0.17

Appendix F.2 (cont.)

Site ID/ Panel ID	Anthropogenic	Rock coating present	Case hardening	Salt efflorescence of subflorescence
Mount Rich	0.00	-1.25	-0.50	0.00
Panel 6	0.00	-2.00	0.00	0.00
	0.00	-1.33	-0.33	0.00
	0.00	-2.50	0.00	0.00
	0.00	-1.77	-0.21	0.00
	0.00	0.51	0.22	0.00
	0.00	0.26	0.05	0.00
Mount Rich	0.00	-1.75	-0.50	0.50
Panel 7	0.00	-1.00	-0.67	0.00
	0.00	-1.00	0.00	0.00
	0.00	-2.50	0.00	0.00
	0.00	-1.56	-0.29	0.13
	0.00	0.62	0.30	0.22
	0.00	0.39	0.09	0.05
Mount Rich	0.00	-1.50	-1.00	0.50
Panel 8	0.50	-1.00	0.00	0.00
	0.00	-1.33	-1.17	0.00
	0.00	-2.50	0.00	0.00
	0.13	-1.58	-0.54	0.13
	0.22	0.56	0.54	0.22
	0.05	0.31	0.30	0.05
Mount Rich	0.75	-1.50	-0.25	0.00
Panel 9	0.00	-2.00	-1.00	0.00
	1.17	-1.17	-0.50	0.17
	0.25	-2.00	0.00	0.00
	0.54	-1.67	-0.44	0.04
	0.45	0.35	0.37	0.07
	0.20	0.13	0.14	0.01
Mount Rich	0.08	-1.18	-0.47	0.26
Site Average	0.03	-1.35	-0.39	0.00
	0.37	-0.97	-0.26	0.03
	0.05	-2.41	0.00	0.00
	0.13	-1.48	-0.28	0.07
	0.14	0.55	0.18	0.11
	0.02	0.31	0.03	0.01

Appendix G:

RASI vs. CSSI score sheets comparisons

G.1 – Front and back of a RASI score sheet. Folding crease along blue line.

Rock Art Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Rock Art Stability Index

Your name:
Date:
Panel:
Panel Location:
Panel Aspect:

Panel Sketch:

G.2 – Centerfold of a RASI score sheet. Folding crease along blue line.

Rock Art Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (Geologically)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz/other three ***can't*** scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

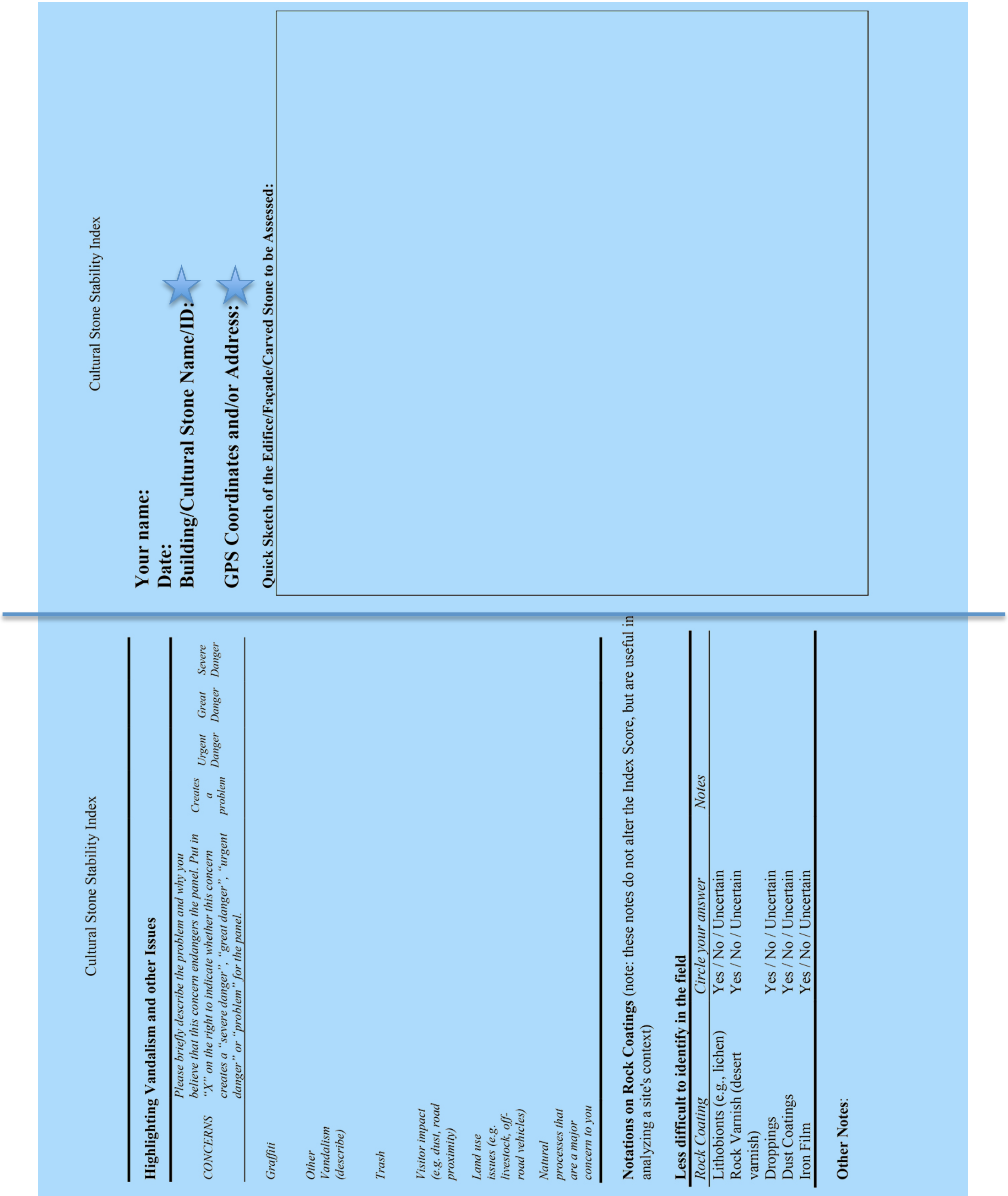
Weaknesses of the Rock Art Panel (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow)	0	1	2	3

Evidence of Large Erosion Events On and Below the Panel (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

Evidence of Small Erosion Events On the Panel (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/rubbing on panel)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Flaking of the weathering rind	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Lithobiont release (when the "dam" of weathering rind decayed rock erodes)	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in pictographs)	0	1	2	3
Rounding and/or blurring of glyph edges	0	1	2	3
Scaling (thicker than flaking; fist- to head-sized)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Panel	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, other)	0	1	2	3
Rock coating present	0	-1	-2	-3
Case hardening (deposits in rock that harden outer shell)	0	-1	-2	-3
Salt Efflorescence or subflorescence	0	1	2	3

G.3 – Front and back of a CSSI score sheet. Folding crease along blue line with differences highlighted.


Cultural Stone Stability Index

Your name:
Date:
Building/Cultural Stone Name/ID:

GPS Coordinates and/or Address:

Quick Sketch of the Edifice/Façade/Carved Stone to be Assessed:

Cultural Stone Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

G.4 – Centerfold of a CSSI score sheet. Folding crease along blue line with differences highlighted.

Cultural Stone Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (overall geologic factors)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Anthropogenic fissures (mortar work)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz scratch/can't scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Cultural Stone (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow, pollution, foot traffic, etc.)	0	1	2	3

Evidence of Large Erosion Events On and Around the Cultural Stone (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots, earthquakes, intersection of fractures, ...)	0	1	2	3

CONTINUE SCORING…CLEARLY circling 0, 1, 2 or 3

Evidence of Small Erosion Events On the Cultural Stone (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/scratching on facade)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Anthropogenic joints/jointing (mortar work)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in inscriptions)	0	1	2	3
Rounding and/or blurring of carved edges or inscriptions	0	1	2	3
Scaling (fist-sized; thicker than flaking)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Carved Stone	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, exhaust, dust, other)	0	1	2	3
Carbonate (showing on the stone surface, NOT part of rock)	0	1	2	3
Case hardening (hardened outer shell)	0	-1	-2	-3
Oxidation (rusting on the stone surface)	0	1	2	3
Rock coating present	0	-1	-2	-3
Salt efflorescence or subflorescence	0	1	2	3

Appendix H:

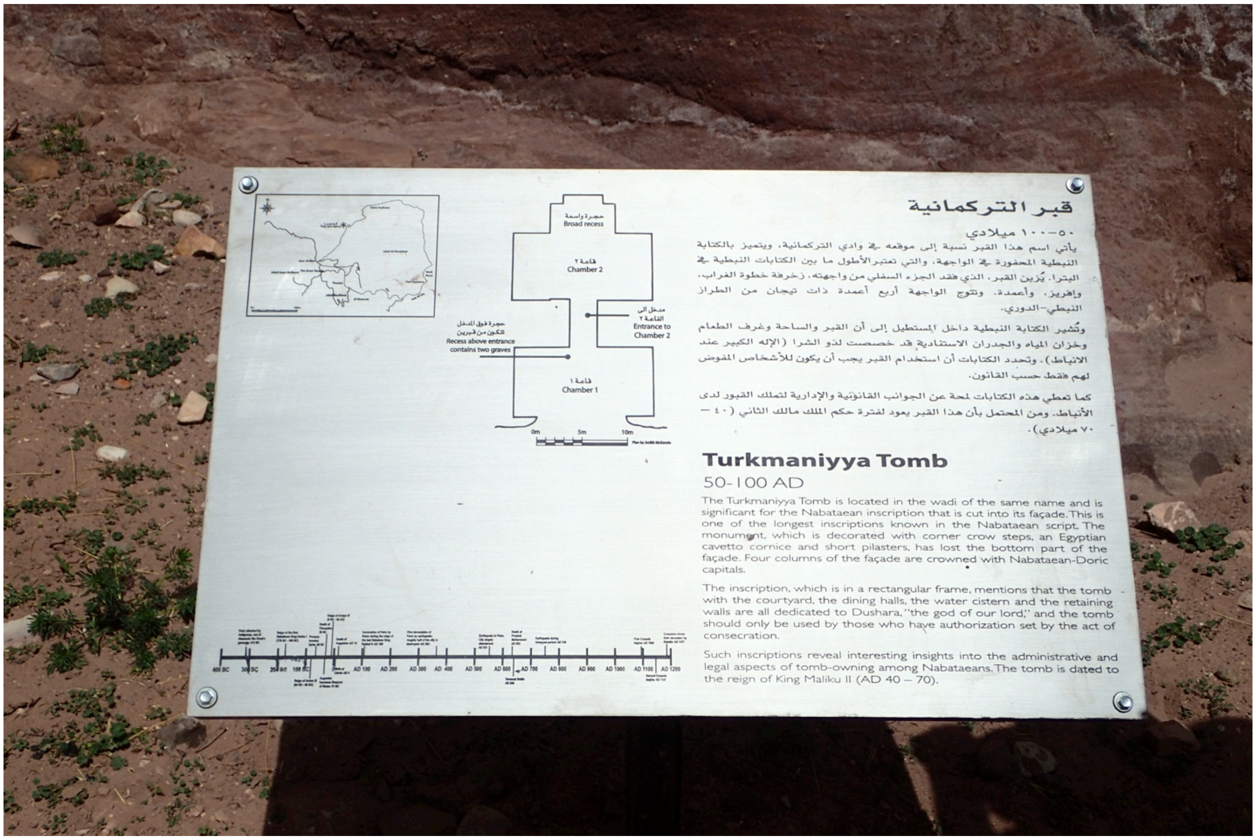
Contextual photographs of the monuments from Case Study #3

H.1 – View of the Monastery (ad-Deir) from a nearby trail to "The Greatest View on Earth" viewpoint overlooking the Wadi Araba with author in the foreground. The trail leading to and from the rest of the city is visible to the far right of the monument in the background. The small building to the far right is a shop/café that sells snacks and drinks with viewing benches along the base of the image. Photograph by Casey Allen, 2016.

H.2 – The Monastery from the ground with fence and sign blocking the entrance for scale. The grandeur and monolithic size of this façade is often difficult to capture in photographs. Photograph by author, 2016.

H.3 – The Turkmanyyia Tomb and surrounding cliff faces with a local school group from Umm Seyhoun visiting for the day. The road from Umm Seyhoun to Petra is just beyond the frame of the photograph to the left. The USAID-erected sign discussing elements of the tomb and its unique Nabataean inscription is to the right of the monument by the road just out of view. Photograph by author, 2016

H.4 – The small informational plaque to the side of the Turkmanyyia Tomb. This tomb is unique not only for its beautifully preserved Nabataean inscription but also in that it sits outside the official park boundaries and is only really visited local school groups or adventurous tourists willing to wander outside Petra proper.



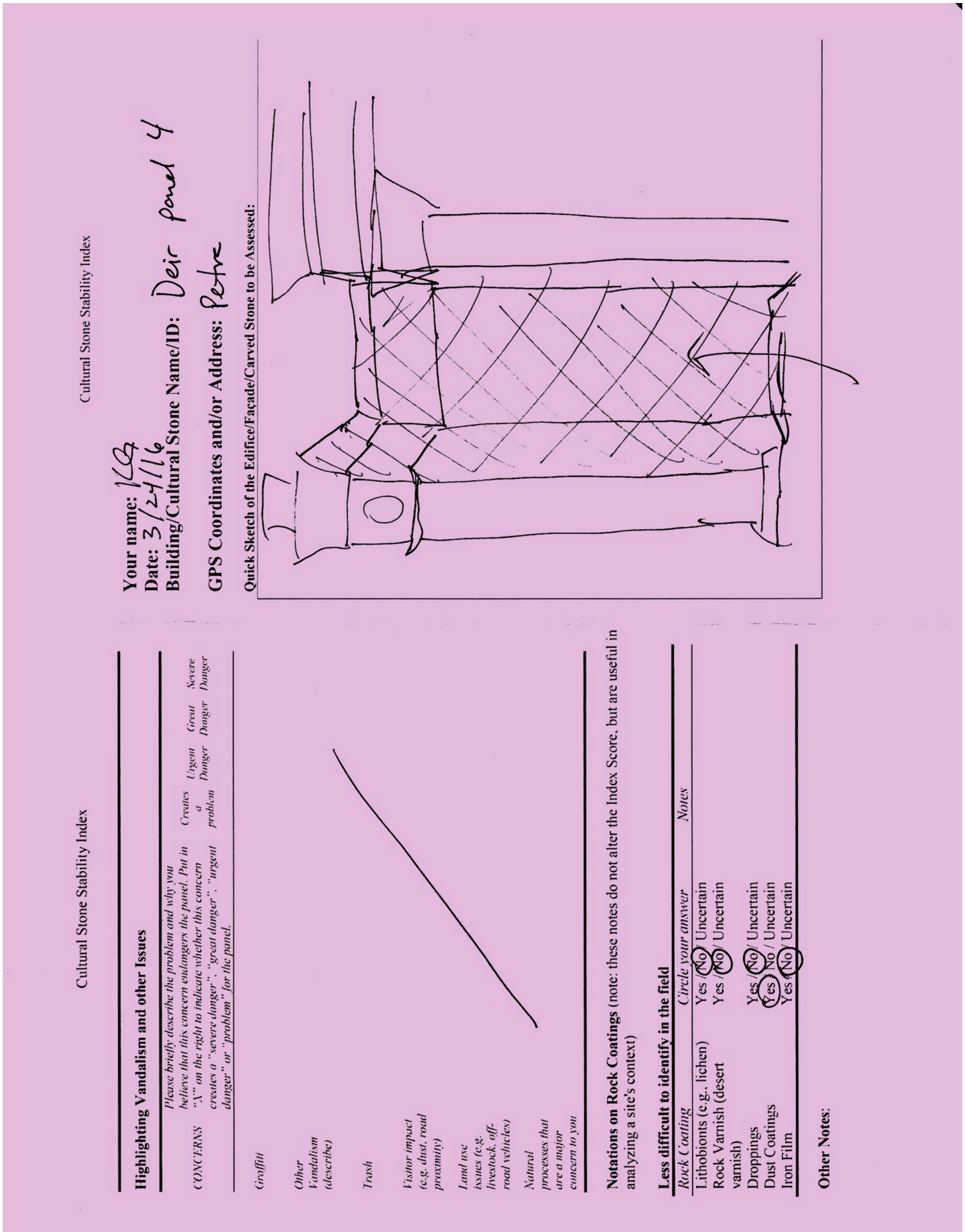
H.5 – The Lion Triclinium and the small canyon in which it is located with Casey Allen and Cayla Kennedy for scale (Permission acquired). Tucked away off the main trail, visitors were significantly fewer while conducting research at this site as opposed to the Deir—the only other research site technically within park boundaries.

Appendix I:

Selected CSSI sheets and photographs from Case Study #3

I.1 – Ad-Deir Panel 4—the upper left enclave on the monument's second story. See the sketch on the corresponding CSSI sheet for panel definition and included architectural elements. The Deir is too big to photograph upper features from the ground so this image was taken from a nearby rock outcrop using a high-definition zoom. Photograph by Casey Allen, 2016.

I.2 – Front and back of completed CSSI score sheet for ad-Deir Panel 4.


Cultural Stone Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Cultural Stone Stability Index

Your name: KG
Date: 3/24/16
Building/Cultural Stone Name/ID: Deir panel 4

GPS Coordinates and/or Address: Petra

Quick Sketch of the Edifice/Façade/Carved Stone to be Assessed:

I.3 – Centerfold of completed CSSI score sheet for ad-Deir Panel 4.

Cultural Stone Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (overall geologic factors)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Anthropogenic fissures (mortar work)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz scratch/can't scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Cultural Stone (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow, pollution, foot traffic, etc.)	0	1	2	3

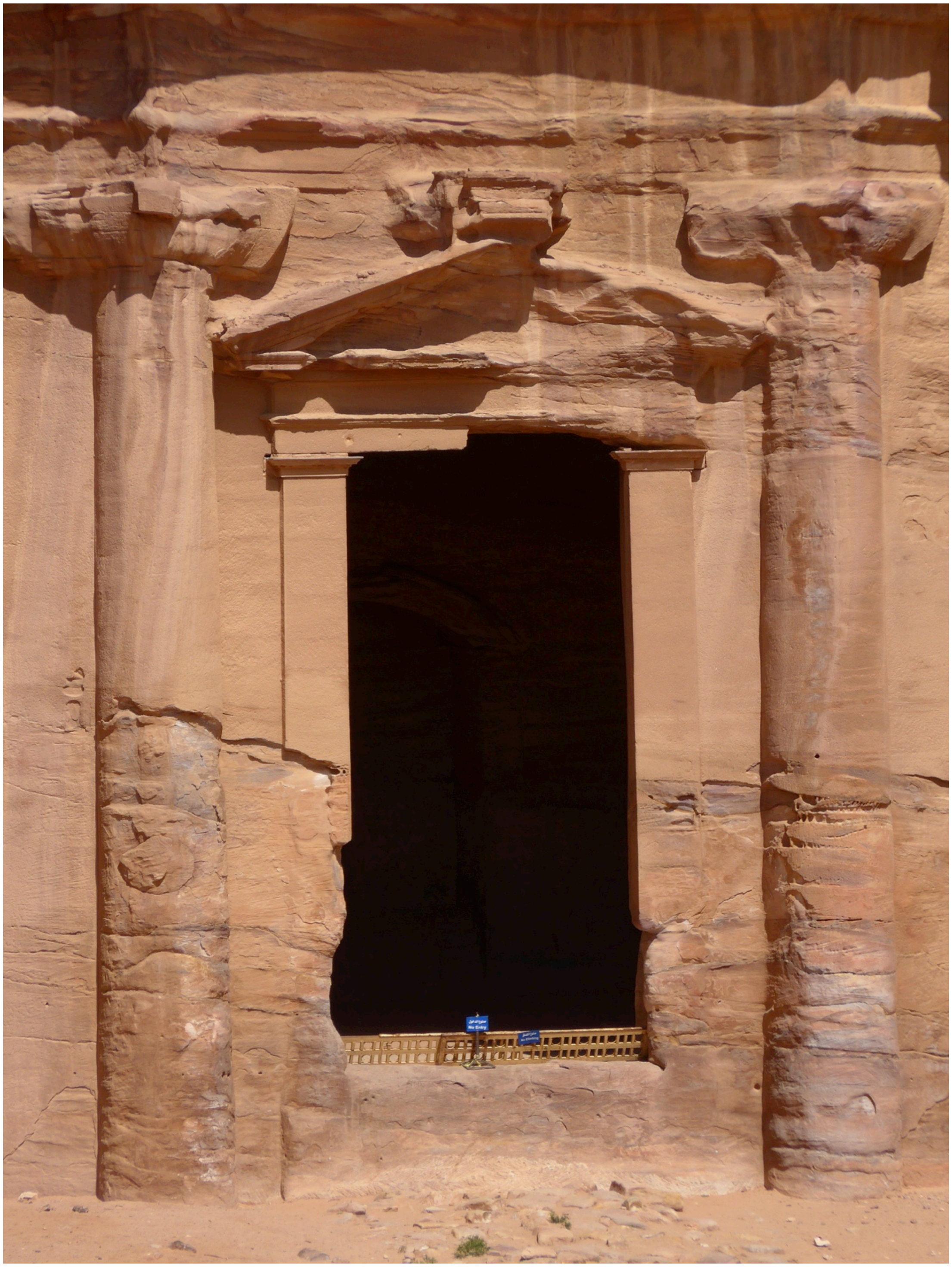
Evidence of Large Erosion Events On and Around the Cultural Stone (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots,	0	1	2	3

CONTINUE SCORING…CLEARLY circling 0, 1, 2 or 3

Evidence of Small Erosion Events On the Cultural Stone (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/scratching on facade)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, …)	0	1	2	3
Anthropogenic joints/jointing (mortar work)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple: millimeter to a few inches in size)	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in inscriptions)	0	1	2	3
Rounding and/or blurring of carved edges or inscriptions	0	1	2	3
Scaling (fist-sized; thicker than flaking)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Carved Stone	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, exhaust, dust, other)	0	1	2	3
Carbonate (showing on the stone surface, NOT part of rock)	0	1	2	3
Case hardening (hardened outer shell)	0	1	-2	-3
Oxidation (rusting on the stone surface)	0	1	2	3
Rock coating present	0	1	-2	-3
Salt efflorescence or subflorescence	0	1	2	3

I.4 – Ad-Deir Panel 14—the main monument door located in the center of the monument's lower story. See sketch on corresponding CSSI sheet for panel definition and included architectural elements. Image taken from ground level. Resultant damage and management concerns have lead the park to forbid entrance to the Deir—an activity previously open to anyone willing to climb the fairly precarious front steps. The fence and sign are visible along the base of the door. Photograph by author, 2016.



I.5 – Front and back of completed CSSI score sheet for ad-Deir Panel 14.

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)	X climbing despite fences & signs				
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

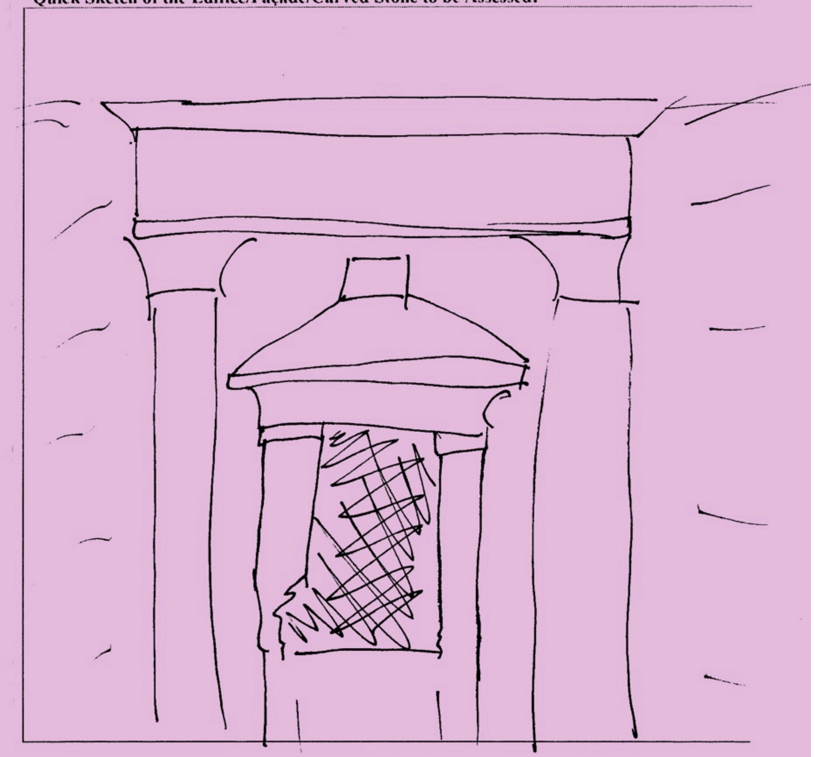
Other Notes:

Cultural Stone Stability Index

Your name: KB
Date: 3/24/16
Building/Cultural Stone Name/ID: Deir panel 14

GPS Coordinates and/or Address: Petra

Quick Sketch of the Edifice/Façade/Carved Stone to be Assessed:



I.6 – Centerfold of completed CSSI score sheet for ad-Deir Panel 14.

Cultural Stone Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (overall geologic factors)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Anthropogenic fissures (mortar work)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz scratch/can't scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Cultural Stone (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow, pollution, foot traffic, etc.)	0	1	2	3

Evidence of Large Erosion Events On and Around the Cultural Stone (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots,	0	1	2	3

CONTINUE SCORING…CLEARLY circling 0, 1, 2 or 3

Evidence of Small Erosion Events On the Cultural Stone (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/scratching on facade)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, …)	0	1	2	3
Anthropogenic joints/jointing (mortar work)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3 right color
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in inscriptions)	0	1	2	3
Rounding and/or blurring of carved edges or inscriptions	0	1	2	3
Scaling (fist-sized; thicker than flaking)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Carved Stone	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, exhaust, dust, other)	0	1	2	3
Carbonate (showing on the stone surface, NOT part of rock)	0	1	2	3
Case hardening (hardened outer shell)	0	-1	-2	-3
Oxidation (rusting on the stone surface)	0	1	2	3
Rock coating present	0	-1	-2	-3
Salt efflorescence or subflorescence	0	1	2	3 Base

I.7 – Turkmanyyia Panel 1—the left contextual panel for the monument. Not wanting to exclude surrounding decay, CSSI assessments were also conducted on immediately surrounding rock faces, most of which were artificially flattened and/or dressed in typical Nabataean style. Photograph by author, 2016.

I.8 – Front and back of completed CSSI score sheet for Turkmanyyia Panel 1.

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you	Birds + cave swallows all around site				

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

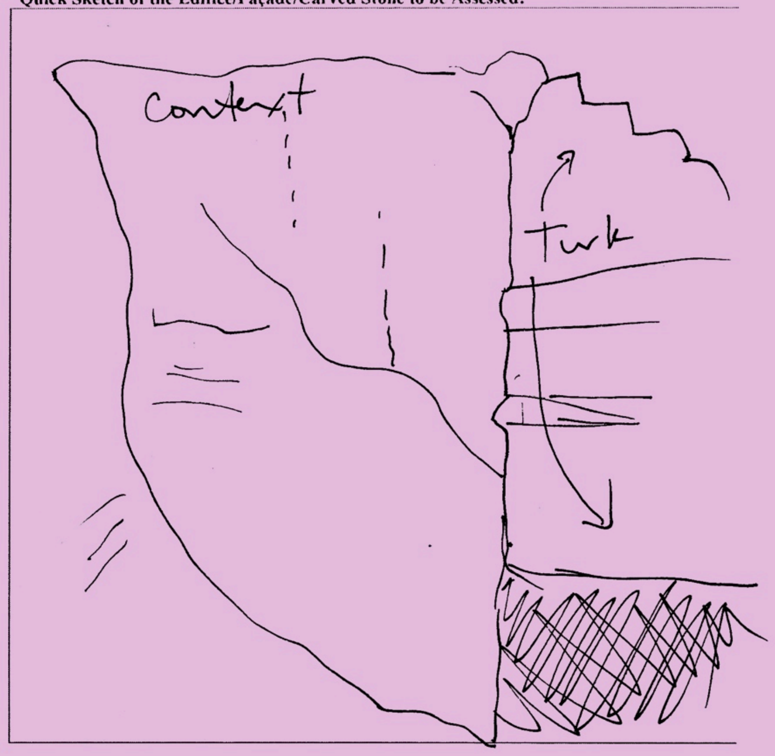
Other Notes:

Cultural Stone Stability Index

Your name: KG
Date: 3/24/16
Building/Cultural Stone Name/ID: Turk panel 1

GPS Coordinates and/or Address: outside Petra

Quick Sketch of the Edifice/Façade/Carved Stone to be Assessed:



I.9 – Centerfold of completed CSSI score sheet for Turkmanyyia Panel 1.

Cultural Stone Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (overall geologic factors)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Anthropogenic fissures (mortar work)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz scratch/can't scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Cultural Stone (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow, pollution, foot traffic, etc.)	0	1	2	3

Evidence of Large Erosion Events On and Around the Cultural Stone (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots,	0	1	2	3

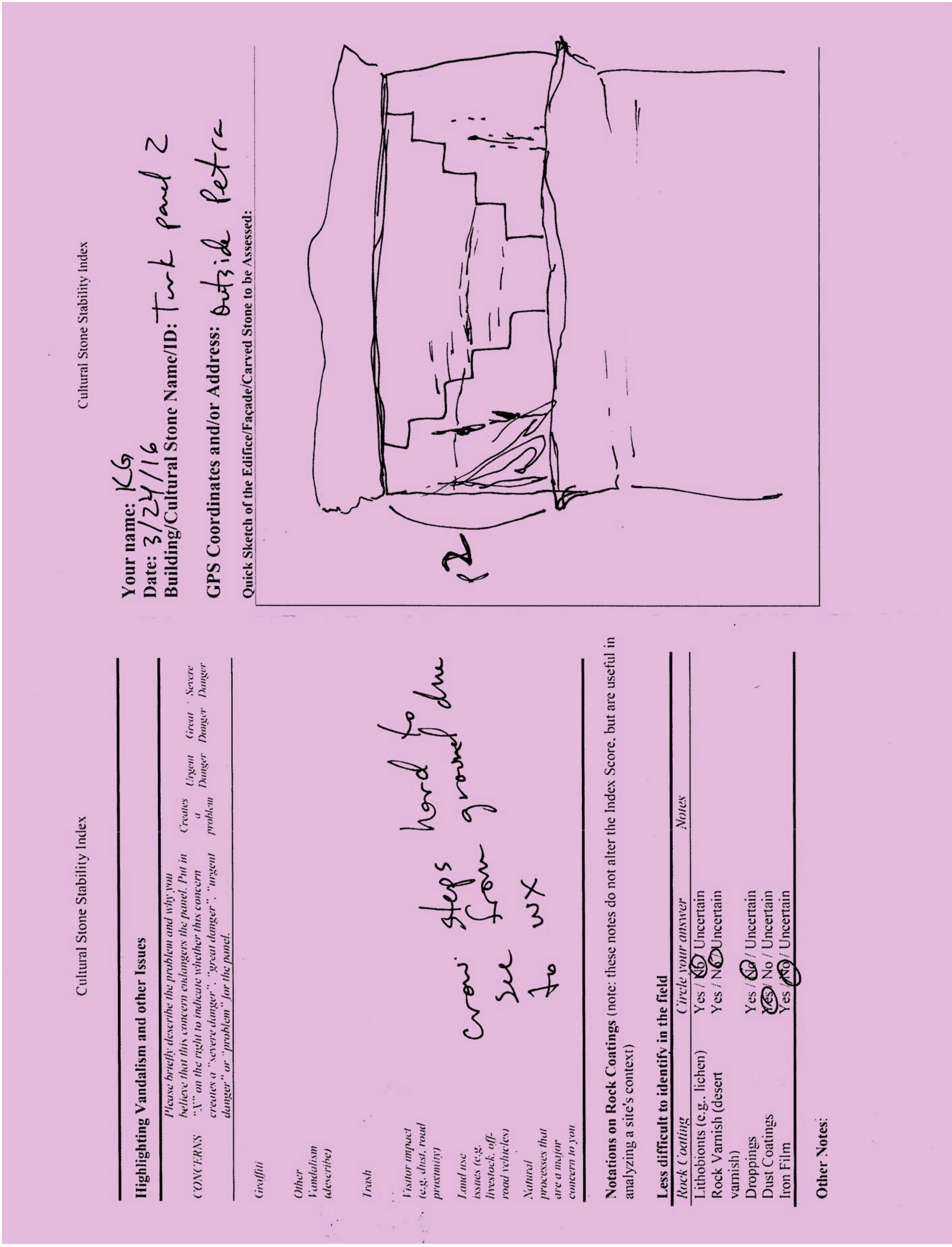
CONTINUE SCORING...CLEARLY circling 0, 1, 2 or 3

Evidence of Small Erosion Events On the Cultural Stone (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/scratching on facade)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, ...)	0	1	2	3
Anthropogenic joints/jointing (mortar work)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in inscriptions)	0	1	2	3
Rounding and/or blurring of carved edges or inscriptions	0	1	2	3
Scaling (fist-sized; thicker than flaking)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Carved Stone	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, exhaust, dust, other)	0	1	2	3
Carbonate (showing on the stone surface, NOT part of rock)	0	1	2	3
Case hardening (hardened outer shell)	0	-1	-2	-3
Oxidation (rusting on the stone surface)	0	1	2	3
Rock coating present	0	-1	-2	-3
Salt efflorescence or subflorescence	0	1	2	3

I.10 – Turkmanyyia Panel 2—the highest carved panel on the tomb including a row of heavily degraded crow steps. See corresponding CSSI sheet for panel boundaries. Having lost much of its defining details, many of the CSSI assessments compared the current status of the monument with assumed baselines based on conceptual sketches from previous archaeological expeditions. Photograph by author, 2016.

I.11 – Front and back of completed CSSI score sheet for Turkmanyyia Panel 2.



Cultural Stone Stability Index

Highlighting Vandalism and other Issues

CONCERNS	Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.	Creates a problem	Urgent Danger	Great Danger	Severe Danger
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)	crow steps hard to see from ground due to wx				
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	Circle your answer	Notes
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

Cultural Stone Stability Index

Your name: KG
Date: 3/24/16
Building/Cultural Stone Name/ID: Turk panel 2

GPS Coordinates and/or Address: outside Petra

Quick Sketch of the Edifice/Façade/Carved Stone to be Assessed:

I.12 – Centerfold of completed CSSI score sheet for Turkmanyyia Panel 2.

Cultural Stone Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (overall geologic factors)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Anthropogenic fissures (mortar work)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz scratch/can't scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Cultural Stone (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow, pollution, foot traffic, etc.)	0	1	2	3

Evidence of Large Erosion Events On and Around the Cultural Stone (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots,	0	1	2	3

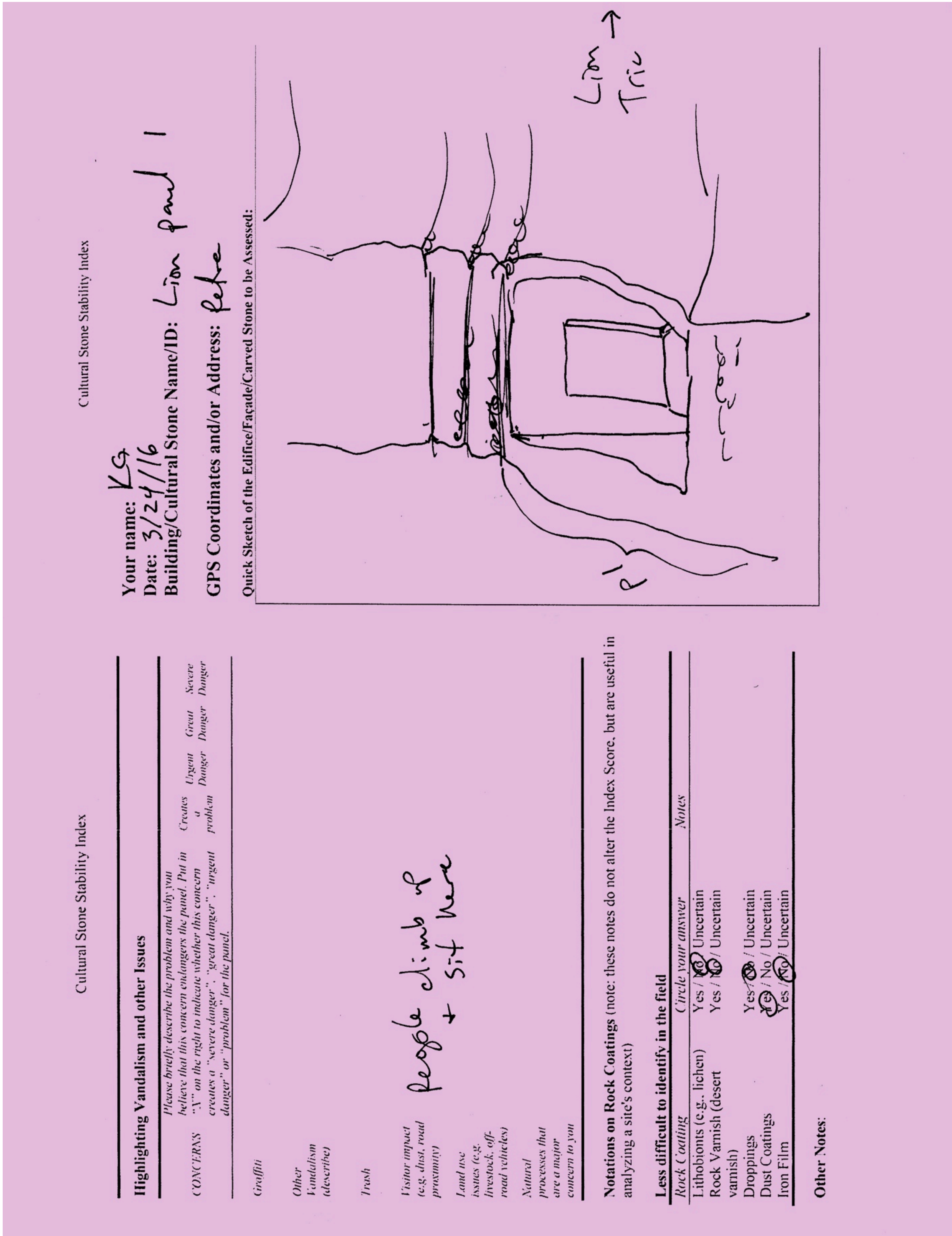
CONTINUE SCORING…CLEARLY circling 0, 1, 2 or 3

Evidence of Small Erosion Events On the Cultural Stone (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/scratching on facade)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, …)	0	1	2	3
Anthropogenic joints/jointing (mortar work)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3 in Tafoni
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple; millimeter to a few inches in size)	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3 left + cent.
Lithobiont pitting	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in inscriptions)	0	1	2	3
Rounding and/or blurring of carved edges or inscriptions	0	1	2	3
Scaling (fist-sized; thicker than flaking)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Carved Stone	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, exhaust, dust, other)	0	1	2	3
Carbonate (showing on the stone surface, NOT part of rock)	0	1	2	3
Case hardening (hardened outer shell)	0	-1	-2	-3
Oxidation (rusting on the stone surface)	0	1	2	3
Rock coating present	0	-1	-2	-3
Salt efflorescence or subflorescence	0	1	2	3

I.13 – Lion Triclinium Panel 1—The small religious niche and surrounding cliff face directly left of the monument when facing the entrance. See the corresponding CSSI sheet for detailed panel definition and included features. Although this niche is technically not part of the Lion Triclinium, its close proximity and presence in Kennedy's historic photograph warranted its inclusion in the assessment. Photograph by author, 2016.

I.14 – Front and back of completed CSSI score sheet for Lion Triclinium Panel 1.


Cultural Stone Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)	People climb up + sit here				
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	Yes / No / Uncertain	

Other Notes:

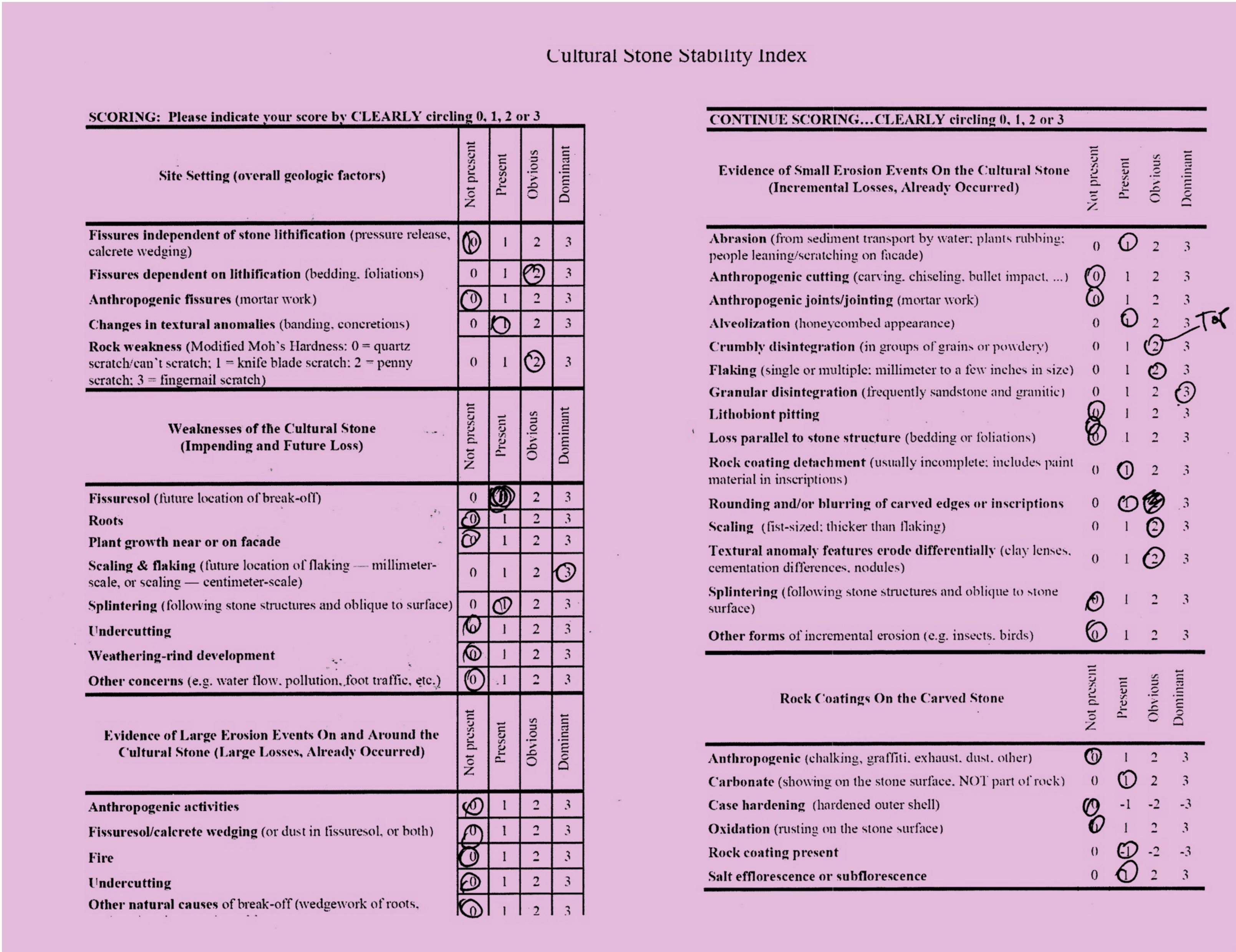
Cultural Stone Stability Index

Your name: KG
Date: 3/24/16
Building/Cultural Stone Name/ID: Lion Panel 1

GPS Coordinates and/or Address: Petra

Quick Sketch of the Edifice/Façade/Carved Stone to be Assessed:

I.15 – Centerfold of completed CSSI score sheet for Lion Triclinium Panel 1.



Cultural Stone Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (overall geologic factors)	Not present	Present	Obvious	Dominant
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3
Fissures dependent on lithification (bedding, foliations)	0	1	2	3
Anthropogenic fissures (mortar work)	0	1	2	3
Changes in textural anomalies (banding, concretions)	0	1	2	3
Rock weakness (Modified Moh's Hardness: 0 = quartz scratch/can't scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3

Weaknesses of the Cultural Stone (Impending and Future Loss)	Not present	Present	Obvious	Dominant
Fissuresol (future location of break-off)	0	1	2	3
Roots	0	1	2	3
Plant growth near or on facade	0	1	2	3
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3
Splintering (following stone structures and oblique to surface)	0	1	2	3
Undercutting	0	1	2	3
Weathering-rind development	0	1	2	3
Other concerns (e.g. water flow, pollution, foot traffic, etc.)	0	1	2	3

Evidence of Large Erosion Events On and Around the Cultural Stone (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Anthropogenic activities	0	1	2	3
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3
Fire	0	1	2	3
Undercutting	0	1	2	3
Other natural causes of break-off (wedgework of roots,	0	1	2	3

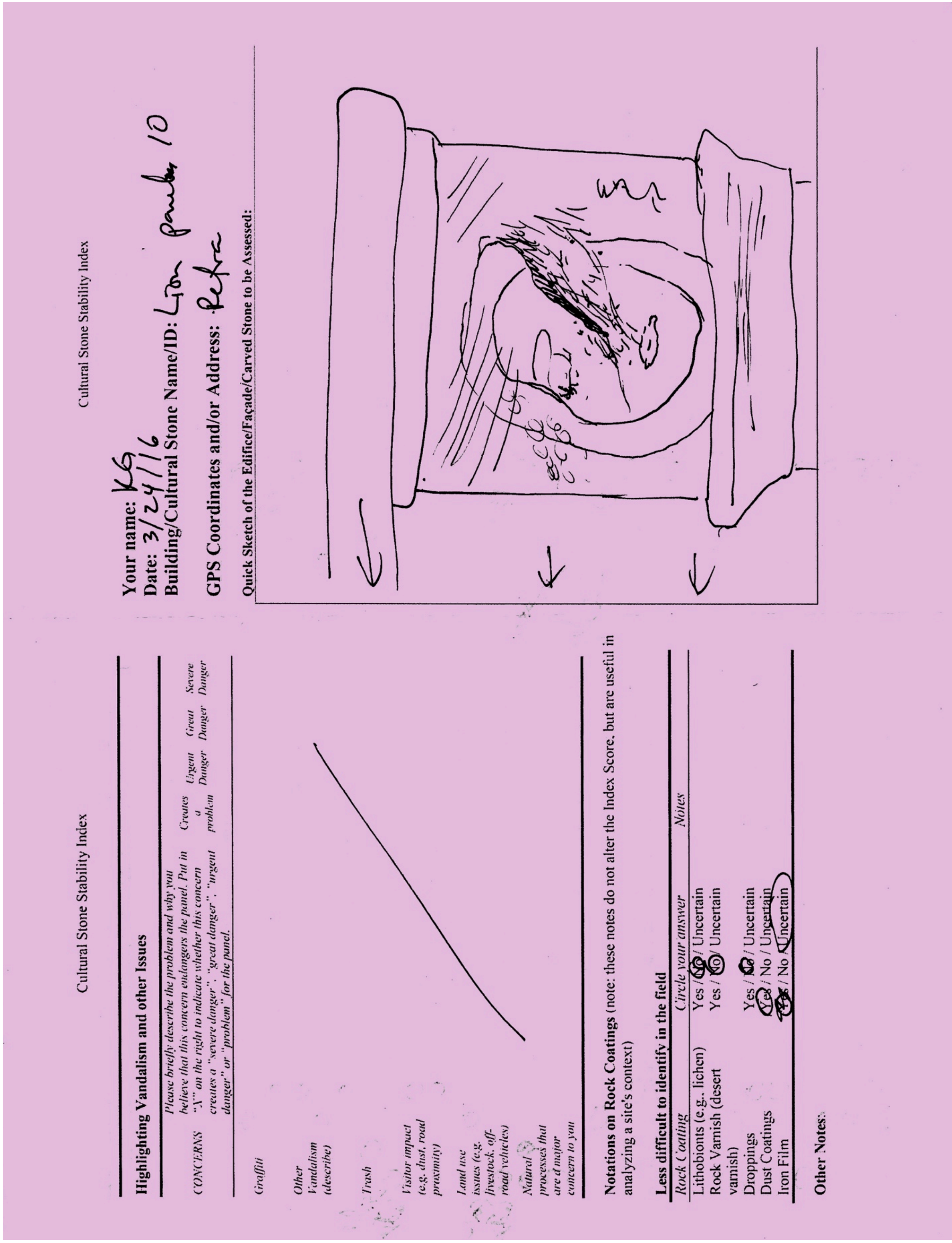
CONTINUE SCORING…CLEARLY circling 0, 1, 2 or 3

Evidence of Small Erosion Events On the Cultural Stone (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant
Abrasion (from sediment transport by water; plants rubbing; people leaning/scratching on facade)	0	1	2	3
Anthropogenic cutting (carving, chiseling, bullet impact, …)	0	1	2	3
Anthropogenic joints/jointing (mortar work)	0	1	2	3
Alveolization (honeycombed appearance)	0	1	2	3 TR
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3
Flaking (single or multiple: millimeter to a few inches in size)	0	1	2	3
Granular disintegration (frequently sandstone and granitic)	0	1	2	3
Lithobiont pitting	0	1	2	3
Loss parallel to stone structure (bedding or foliations)	0	1	2	3
Rock coating detachment (usually incomplete; includes paint material in inscriptions)	0	1	2	3
Rounding and/or blurring of carved edges or inscriptions	0	1	2	3
Scaling (fist-sized; thicker than flaking)	0	1	2	3
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3
Splintering (following stone structures and oblique to stone surface)	0	1	2	3
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3

Rock Coatings On the Carved Stone	Not present	Present	Obvious	Dominant
Anthropogenic (chalking, graffiti, exhaust, dust, other)	0	1	2	3
Carbonate (showing on the stone surface, NOT part of rock)	0	1	2	3
Case hardening (hardened outer shell)	0	-1	-2	-3
Oxidation (rusting on the stone surface)	0	1	2	3
Rock coating present	0	-1	-2	-3
Salt efflorescence or subflorescence	0	1	2	3

I.16 – Lion Triclinium Panel 10—a close up assessment of the carved face on the top right capital of the monument with adjacent mantels. Too high to photograph from the base of the monument, the image had to be captured from a nearby cliff using a high-definition zoom. Photograph provided by Casey Allen, 2016.

I.17 – Front and back of completed CSSI score sheet for Lion Triclinium Panel 10.



Cultural Stone Stability Index

Highlighting Vandalism and other Issues

CONCERNS	*Please briefly describe the problem and why you believe that this concern endangers the panel. Put in "X" on the right to indicate whether this concern creates a "severe danger", "great danger", "urgent danger" or "problem" for the panel.*	*Creates a problem*	*Urgent Danger*	*Great Danger*	*Severe Danger*
Graffiti					
Other Vandalism (describe)					
Trash					
Visitor impact (e.g. dust, road proximity)					
Land use issues (e.g. livestock, off-road vehicles)					
Natural processes that are a major concern to you					

Notations on Rock Coatings (note: these notes do not alter the Index Score, but are useful in analyzing a site's context)

Less difficult to identify in the field

Rock Coating	*Circle your answer*	*Notes*
Lithobionts (e.g., lichen)	Yes / No / Uncertain	
Rock Varnish (desert varnish)	Yes / No / Uncertain	
Droppings	Yes / No / Uncertain	
Dust Coatings	Yes / No / Uncertain	
Iron Film	~~Yes~~ / No / Uncertain	

Other Notes:

Cultural Stone Stability Index

Your name: KG
Date: 3/24/16
Building/Cultural Stone Name/ID: Lion panel 10

GPS Coordinates and/or Address: Petra

Quick Sketch of the Edifice/Façade/Carved Stone to be Assessed:

I.18 – Centerfold of completed CSSI score sheet for Lion Triclinium Panel 10.

Cultural Stone Stability Index

SCORING: Please indicate your score by CLEARLY circling 0, 1, 2 or 3

Site Setting (overall geologic factors)	Not present	Present	Obvious	Dominant	
Fissures independent of stone lithification (pressure release, calcrete wedging)	0	1	2	3	
Fissures dependent on lithification (bedding, foliations)	0	1	2	3	
Anthropogenic fissures (mortar work)	0	1	2	3	
Changes in textural anomalies (banding, concretions)	0	1	2	3	
Rock weakness (Modified Moh's Hardness: 0 = quartz scratch/can't scratch; 1 = knife blade scratch; 2 = penny scratch; 3 = fingernail scratch)	0	1	2	3	
Weaknesses of the Cultural Stone (Impending and Future Loss)	Not present	Present	Obvious	Dominant	
Fissuresol (future location of break-off)	0	1	2	3	
Roots	0	1	2	3	
Plant growth near or on facade	0	1	2	3	
Scaling & flaking (future location of flaking — millimeter-scale, or scaling — centimeter-scale)	0	1	2	3	face
Splintering (following stone structures and oblique to surface)	0	1	2	3	ledge
Undercutting	0	1	2	3	
Weathering-rind development	0	1	2	3	
Other concerns (e.g. water flow, pollution, foot traffic, etc.)	0	1	2	3	
Evidence of Large Erosion Events On and Around the Cultural Stone (Large Losses, Already Occurred)	Not present	Present	Obvious	Dominant	
Anthropogenic activities	0	1	2	3	
Fissuresol/calcrete wedging (or dust in fissuresol, or both)	0	1	2	3	
Fire	0	1	2	3	
Undercutting	0	1	2	3	
Other natural causes of break-off (wedgework of roots,	0	1	2	3	

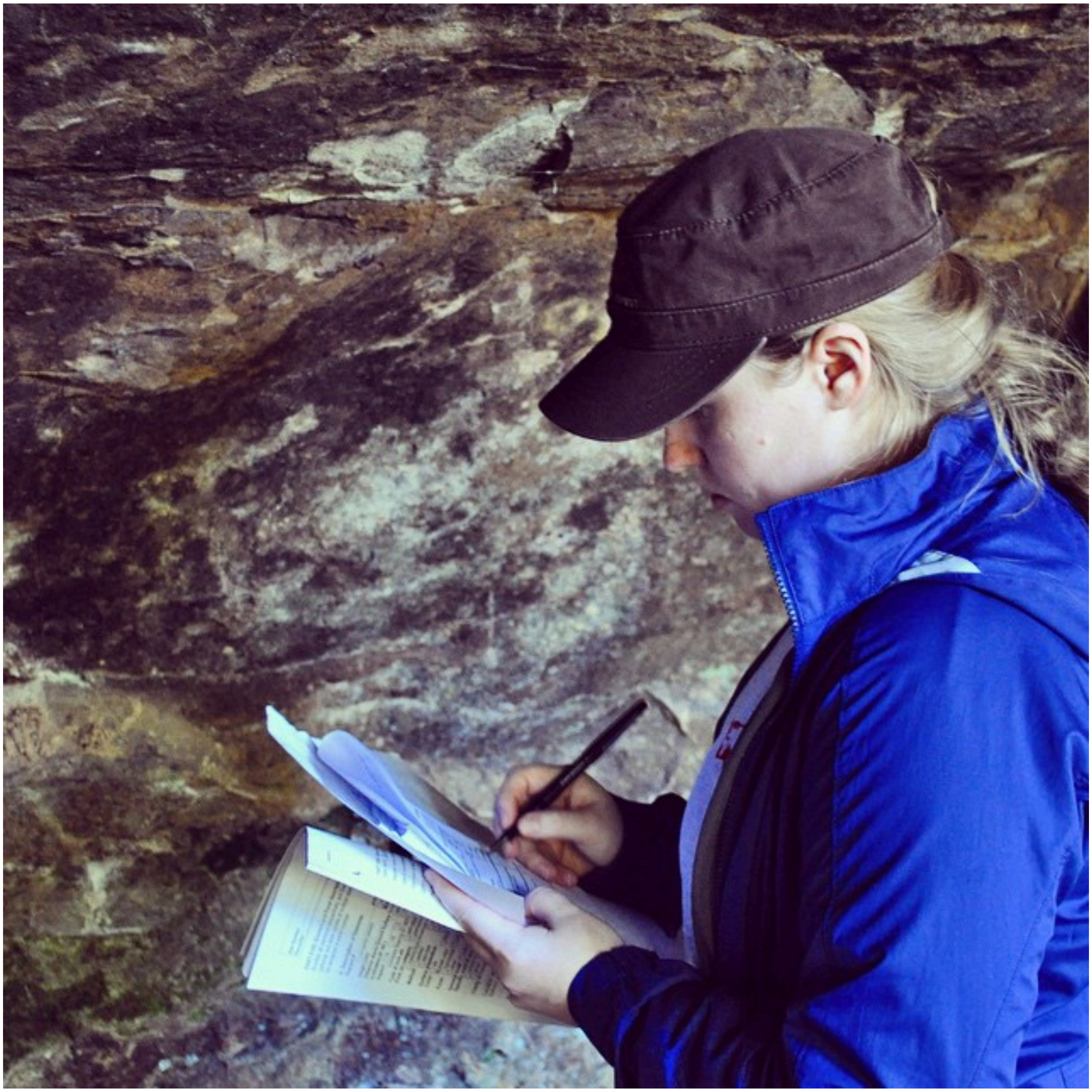
CONTINUE SCORING…CLEARLY circling 0, 1, 2 or 3

Evidence of Small Erosion Events On the Cultural Stone (Incremental Losses, Already Occurred)	Not present	Present	Obvious	Dominant	
Abrasion (from sediment transport by water; plants rubbing; people leaning/scratching on facade)	0	1	2	3	
Anthropogenic cutting (carving, chiseling, bullet impact, …)	0	1	2	3	
Anthropogenic joints/jointing (mortar work)	0	1	2	3	
Alveolization (honeycombed appearance)	0	1	2	3	
Crumbly disintegration (in groups of grains or powdery)	0	1	2	3	
Flaking (single or multiple: millimeter to a few inches in size)	0	1	2	3	sides
Granular disintegration (frequently sandstone and granitic)	0	1	2	3	ledge
Lithobiont pitting	0	1	2	3	
Loss parallel to stone structure (bedding or foliations)	0	1	2	3	
Rock coating detachment (usually incomplete; includes paint material in inscriptions)	0	1	2	3	face
Rounding and/or blurring of carved edges or inscriptions	0	1	2	3	ledge
Scaling (fist-sized; thicker than flaking)	0	1	2	3	
Textural anomaly features erode differentially (clay lenses, cementation differences, nodules)	0	1	2	3	
Splintering (following stone structures and oblique to stone surface)	0	1	2	3	
Other forms of incremental erosion (e.g. insects, birds)	0	1	2	3	
Rock Coatings On the Carved Stone	Not present	Present	Obvious	Dominant	
Anthropogenic (chalking, graffiti, exhaust, dust, other)	0	1	2	3	
Carbonate (showing on the stone surface, NOT part of rock)	0	1	2	3	
Case hardening (hardened outer shell)	0	-1	-2	-3	
Oxidation (rusting on the stone surface)	0	1	2	3	
Rock coating present	0	-1	-2	-3	
Salt efflorescence or subflorescence	0	1	2	3	

Appendix J:

Selected photographs of author in the field

J.1 – The author conducting a RASI evaluation at the Narrows Rock Shelter, Arkansas. With my permission, an Arkansas Archaeological Survey employee, Jamie Brandon, took the photograph for later use in online promotional material for the Survey. 2014.



J.2 – A short article on the front page of a local newsletter, Fairfield Bay News, highlighting our rock art assessment at the Edgemont Rock Shelter. While I was conducting RASI analyses, AAR Survey employees Jerry and Jamie were conducting a survey of the shelter.

Archeologists Visit Indian Rock Cave... Dr. Jamie Brandon, right, Research Station Archeologist with Arkansas Archeological Survey from the University of Arkansas Fayettvile, along with Jerry Hillard, left, also with Archeological Survey, and PHD Grad Candidate, Kaelin Groom, visit the Indian Rock Cave in Fairfield Bay to study the carvings and do mapping of the cave. Kaelin, is taking photos of the carvings and will compare with photos taken in the 1930s to see how much the carvings have deteriorated. The team will be coming again to spend another three days researching the smaller cave as they found more carvings to study. This cave is one of three that is studied in the Ozarks. While here, they also found a Catlinite Disk Pipe dated 1400 A.D. to 1600 A.D in the museum, which is on loan from the University of Arkansas Museum. This pipe is often used in a ceremony called the “Calumet” and is commonly known as a “Peace Pipe.”

J.3 – The author conducting a RASI assessment of the “Cat Glyphs” at Mt. Rich, Grenada. This was the first time these petroglyphs had ever been geologically analyzed. Photograph provided by Casey Allen, 2012.

J.4 – The author explaining RASI and leading a group assessment of Duquesne Bay Panel 1 as part of the University of Colorado Denver study abroad program *Sustainability in the Caribbean*. Photograph provided by Casey Allen, 2015.

J.5 – Author examining Mount Rich Panel 2, Grenada. The St. Patrick River was particularly high during this visit, as evident from my wet shoes and pants. Photograph by Casey Allen, 2016. Although this panel had been cleaned the previous year, new mosses, algae, and plant debris coatings have recovered the boulder.

J.6 – The author and Casey Allen riding in the back of a Bedouin pick up truck on the way to the "back door" of Petra for the first day of fieldwork. This was the first time for Casey to see most of Petra, including the Deir—the first monument seen when entering from the rear. This trip was at the end of January, so it was quite chilly. Photograph by author, 2016.

J.7 – The author taking a repeat photograph of the Deir. The most effective method of replication was holding a copy of the historic photograph on my cell phone directly above or below my camera while trying to get the same shot. That way new and old images could be compared in real time. Photograph by Casey Allen.

J.8 – The small timid dog and stray cats that joined our group—Tom and Kathy (pictured with permission) Groom, Casey Allen, and myself—while I conducted preliminary scouting and research at the Deir in Petra, Jordan. There are several stray animals in the park and most are relatively friendly, albeit dirty and emaciated, as food and scraps from tourists are their primary food source. Photograph by author, 2016.

J.9 – Taking a lunch break in Petra at the Temple of the Winged Lions. Pictured from left to right: Kathy Groom, Tom Groom, Kaelin Groom, and Casey Allen. Selfie by Kathy Groom on cell phone—explanation for fuzzy resolution/out of focus. Permission from each individual obtained.

J.10 – From left to right: Kaelin Groom, Dr. Tom Paradise, and Peter von Groote in Wadi Mousa posing in front of a sun set over Petra. Photograph was taken by a local contact, 2013.

J.11 – From left to right: Tom Paradise, Chris Angel, Kaelin Groom, and Peter von Groote. Photo taken by Danusia (Friend of Dr. Paradise) during 2013 summer field research. Image provided by Tom Paradise, 2017.